Interim Report

DOUGLAS-FIR TUSSOCK MOTH RESEARCH AND PILOT TEST PROGRAM

SEASON OF 1974

by

U.S. FOREST SERVICE AND COOPERATORS

U.S. Forest Service
Pacific Northwest Forest and Range Experiment Station
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CONTENTS

INTRODUCTION

The Douglas-fir tussock moth is a destructive native insect that reaches epidemic levels in western forests at irregular intervals, but averaging about every 7-10 years. National attention was focused on the insect in 1972 when a severe outbreak appeared on some 200,000 acres of Douglas-fir and true fir forests in eastern Oregon and Washington. Outbreaks increased in 1973 to nearly 800,000 acres when additional areas were discovered in Idaho, Montana, and other areas of Washington and Oregon.

Because DDT was the only effective control for the tussock moth, its use for aerial spraying in 1973 was requested by the U.S. Department of Agriculture, under exemption provisions of the Federal Insecticide, Fungicide, and Rodenticide Act. The request was denied by the Environmental Protection Agency. Damage in 1973 increased greatly and another request for use of DDT, if needed in 1974, was made. The request was granted by EPA Order on February 28 (Federal Register, Vol. 39, No. 4, March 5, 1974).

However, granting of the request was provisional to certain "Research Requirements" as listed under Section IIIB of the Order. The Order further specified that results of the required research, to be done in calendar year 1974, be reported to EPA by December 1, 1974. On May 9, John R. McGuire, Chief of the the U.S. Forest Service, wrote Russell E. Train, EPA Administrator, of Forest Service plans for carrying out the activities related to the EPA Order. Subsequently, he assigned Robert E. Buckman, Director, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon, to coordinate the Forest Service research efforts and to serve as liaison with EPA on research matters.

This report describes results of research and pilot testing conducted by the Forest Service and its cooperators in 1974. It includes sections on (1) background and history of the current outbreak, (2) a summary of research findings in 1974, and (3) an Appendix of 14 reports on individual studies and tests carried out during the 1974 season, including maps of test plot location.

Background and History of the Current Outbreak

The present tussock moth situation in the Northwest first developed to epidemic proportions in 1971 on several scattered areas in north-central Washington and on the eastern foothills of Mt. Emily in eastern Oregon. A number of tests of possible substitutes for DDT were carried out in those areas during 1972. Early in 1972 defoliation began to appear on much larger areas in eastern Oregon and eastern Washington. An extensive insect survey was made during the fall of 1972 which showed that considerable additional and more serious damage would occur during 1973 if control action was not taken.

A request to use DDT during 1973 was made by USDA to EPA, but it was denied. By the end of 1973, nearly 800,000 acres of forest land in Oregon, Washington, and Idaho had been defoliated to some degree. Field experiments or pilot tests of four chemical and two microbial insecticides, as well as research on population dynamics, impact, sex pheromone, and other problems, were accelerated during 1973. The amount of timber killed by the end of 1973 was estimated at about 842 million board feet with a loss of about $31 million, after values recovered by timber salvage were subtracted. Added to the dollar loss were an estimated $12.6 million for reforesting the more heavily damaged areas and about $15 million for increased fire protection costs.

Surveys were conducted again during the fall of 1973; these surveys showed that tussock moth activity was occurring in many new locations while declining in some of the older areas. Feeding had subsided on many of the originally infested areas because insect populations had collapsed, due to starvation and other natural factors. However, the survey showed that direct control action would likely be necessary on 482,000 acres during 1974. This included 263,000 acres in the Blue Mountains of Oregon and Washington; 114,000 acres on the Colville Indian Reservation and adjacent lands in Washington; and 105,000 acres in Idaho.

In 1974, some 74,000 infested acres were set aside for testing chemical or biological insecticides and for other kinds of research. These areas met criteria for operational treatment and were almost exclusively on National Forest lands, since private owners were most reluctant to permit use of their lands for testing new control methods with uncertain results. Study plans included testing of the natural virus and the bacterium *Bacillus thuringiensis* on 29,000 acres in Idaho. Several chemicals, including Dylox, Sevin-4-oil, and reduced dosages of DDT, were scheduled for aerial testing on a 25,000-acre area in Oregon. Ground application screening tests were planned for 15 candidate insecticides. Several new studies concerning population dynamics, damage impacts, and host relationships were initiated; some of these were contracted to universities and colleges.

SUMMARY OF 1974 RESEARCH

Research and pilot control testing on the tussock moth were greatly accelerated in 1974 (these two activities are treated collectively as "Research" in the EPA Order). The increased level of study was made possible mainly by Supplemental FY 1974 Congressional appropriations of $240,000 for research and $600,000 for pilot tests. An additional $100,000 was reprogramed to Douglas-fir tussock moth research from other Forest Service funds. When added to existing base funding, the Forest Service spent an estimated $2 million on a tussock moth research and development program in FY 1974.

Major efforts were mounted by the Pacific Northwest and Pacific Southwest Forest and Range Experiment Stations, and Regions 1 and 6 of the Forest Service. Cooperative and individual contributions were also made by the States of Oregon, Washington, Idaho, and Montana, several universities working on research contracts, private forest industry, chemical companies, and others.

Fourteen studies are summarized in the Appendix. Research initiated earlier is drawn upon where appropriate. They are further briefed and highlighted in the following statements.

A. Population Dynamics and Impact

Investigations of the dynamics and impact of tussock moth populations were included in the EPA "Research Requirements." The emphasis was placed on "improving ability to predict infestation intensity and resultant tree damage from early indicators." An understanding of pest and host dynamics is necessary for this purpose; such an understanding comes from studying an outbreak from its inception through complete collapse and then studying tree damage for several additional years. Investigations of the dynamics and impact of tussock moth populations have been underway by the Forest Service for a number of years.

With the advent of the extensive outbreak of the tussock moth in northeastern Oregon in mid-1972, a new comprehensive study was established to investigate population change and impact under a wide range of forest conditions. Because the area studied transects only a portion of the total infestation, the results must be evaluated very carefully. They are subject to further analysis.

Study No. 1 in the Appendix deals primarily with the major findings from those specific population-impact studies.

The studies were aimed at obtaining information on population change, natural mortality, defoliation, and tree damage under natural conditions. This information will form the basis for predicting what will happen if the resource manager selects the alternative of "no action."

Several studies are complete now, and some important insect population and host damage relationships are emerging. The decline phase or population collapse occurring over much of the Blue Mountain outbreak in late 1973 after severe feeding injury occurred. There were adjacent outbreaks which first appeared in 1973 and, therefore, didn't decline until summer of 1974. Many of these areas were used for various insecticide tests.

Natural causes of tussock moth mortality were more difficult to quantify. Mortality of early instar larvae was significant in 1973 and was attributed to dispersal and starvation. Natural virus played an important role later in the cycle by causing an increasing amount of mortality in late 1973 and early 1974. Present sampling techniques can be used to predict virus disease in populations.

Tree defoliation in 1973 was strongly related to the rapid decline in numbers of young larvae. New foliage was destroyed within 2 weeks, and many larvae died before they were mature enough to feed on older foliage. This resulted in complete loss of all new foliage and lighter feeding on old foliage of grand fir than on Douglas-fir. Foliage recovery occurred on trees of both species in 1974.

Mortality was strongly related to the differential defoliation of grand fir and Douglas-fir, with Douglas-fir sustaining a proportionally larger volume of mortality. Stands in the Blue Mountains containing a large component of Douglas-fir consistently suffered more tree damage than pure grand fir stands in 1973. Final damage figures will require additional years of study.

B. Microbial Insecticides

Followup on 1973 field experiments.--The results of field tests with the microbial insecticides nucleopolyhedrosis virus and *Bacillus thuringiensis* (*B.t.*) conducted in 1973 are in the process of publication. The field plots were examined again in 1974 to determine long-term effectiveness of the treatments. All plots treated with the virus formulations and those with the most successful *B.t.* formulation contained negligible tussock moth populations in 1974, while the populations in the untreated control plots and the plots treated with a *B.t.*-BioFilm formulation continued at visible defoliation levels through most of the 1974 season. (See Appendix, Study No. 2, for more complete presentation of findings.)

1974 field experiments.--Ground applications of *Bacillus thuringiensis* were tested against Douglas-fir tussock moth populations on ornamental trees in Santa Fe, New Mexico. *B.t.* applied by hydraulic sprayer proved very effective in controlling the tussock moth. (See Appendix, Study No. 14 for a more detailed report.)

Thirty to 40 egg masses were tagged per spray block and examined every other day to determine when spraying would begin. Spraying was to begin when 50 percent of the larvae had developed to second instar.

Pretreatment Evaluations

Egg masses were collected from 48 sections as part of the fall 1973 egg mass survey.[3/] These were used for virus and egg parasite determination.

If an average of 5 percent or more of the larvae from an area were infected with naturally occurring virus, that section was deleted from the test site. Those sections with virus levels between 1 and 5 percent were evaluated further before deleting them from the test. Areas with 1 percent or less virus were to be treated. Alternative test sites were to be selected if virus levels were too high in the proposed test areas.

Method of Application

Application was to be by helicopter in all blocks scheduled for treatment with microbial insecticides.

OPERATIONAL PROBLEMS

Formulation of Microbial Insecticides

Examination of materials revealed that the molasses contained small particles of a solid material. These particles would not pass through 100-mesh screen and would have resulted in clogged or partially clogged nozzle screens on the aircraft spray system and an inconsistent flow rate.

Discussions with representatives of Cargills indicated that the solid material in the molasses was vermiculite. Santoquin, an additive to prevent fermentation, formulated on a vermiculite base had been added to the molasses. Contract specifications called for the addition of liquid santoquin. Prior to spraying, attempts to screen a diluted molasses-water mix through a 100-mesh screen failed, resulting in clogged nozzle screen within 20 minutes when tested in a simulated spray boom at 40 pounds per square inch. The material was rejected and plans were reluctantly made to substitute BioFilm, a commercial surfactant, for the molasses.

Three women filtering and screening Douglas-fir tussock moth body parts and hairs from the virus spray exhibited symptoms of contact

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3/ S. Tunnock and R. L. Livingston. 1974. Potential Douglas-fir tussock moth damage in northern Idaho in 1974 based on a 1973 fall egg-mass survey. I&D Report 74-4. USDA Forest Service, Northern Region.

dermatitis, typical of exposure to mature tussock moth larvae or pupal cases. Symptoms of dermatitis persisted for 2 weeks.

Decline of Tussock Moth Populations in Test Sites

Installation of spray blocks in the Selway test site in late May and early June indicated that tussock moth egg mass populations were lower than earlier egg mass surveys indicated. In addition access and acres of clearcut units within the test site made it virtually impossible to include nine blocks within the area available for testing. On June 4, a decision was made to eliminate the three virus test blocks and proceed with a design which included three *B.t.* blocks and three check blocks.

A prespray larval sample taken June 24 indicated that tussock moth population densities were too low to support a valid pilot control project in the Selway test site; therefore, the entire Selway pilot project was aborted (table 1). Larval development at this time was:

Instar	Percent
First	4
Second	83
Third	13

Similar observations were being made on tussock moth populations in the Coeur d'Alene Mountain test site. Prespray samples in late June showed Douglas-fir tussock moth populations were lower than the number needed to meet criteria established for *B.t.* and virus for this pilot test (table 2). Minimum population density levels established prior to start of the project were 20 larvae per 1,000 square inches of foliage in *B.t.* spray blocks and 50 larvae per 1,000 square inches of foliage in virus spray blocks. Since these criteria could not be met, the entire project was aborted on June 29.

Natural Mortality Factors

Empirical observation by numerous individuals associated with the project indicated that the early decline of larval populations in the Coeur d'Alene Mountain test site was due to a number of factors; these included low egg viability possibly due to climatic abnormalities which occurred in late winter or early spring, predation by ants, and heavy populations of an unidentified aphid which infested the new growth in grand fir and produced large volumes of honeydew which prevented first-instar larvae from feeding and entrapped young larvae when exposed to honeydew-covered foliage. Honeydew-covered foliage resulted in dispersal of tussock moth larvae to new foliage or host trees. This resulted in mortality of some larvae as they did not reach suitable host trees.

After the project was aborted, tussock moth populations were monitored to determine the effect of natural factors on the remaining population in the Coeur d'Alene Mountain test site.

Two 15-inch branches were removed from each of 80 trees in each of the nine spray units at 10-day intervals following the prespray samples. When present, 10 larvae and/or pupae were collected from each tree on each sample date and placed separately in petri dishes, then returned to the laboratory. At the laboratory a piece of artificial media was placed in each petri dish, the dish was labeled as to block, tree number, and date, and placed on shelves for rearing.

A total of 6,689 tussock moth larvae were reared to determine mortality from various causes. Of the tussock moths reared, 48.9 percent emerged as adults; 36.7 percent died from unknown causes; 9.2 percent died from hymenopterous parasites; 3.4 percent died from virus; and 1.8 percent died from dipterous parasites (table 3).

Parasitism by hymenopterans ranged from 0 to 26 percent, with highest percent parasitism occurring in larvae collected in the 35-day sample. Larvae were mostly fifth and sixth instars by this time. Parasitism by dipterans ranged from 0 to 32 percent, with highest parasitism occurring in the pupal sample. Mortality from virus ranged from 0 to 11 percent, with highest larval mortality occurring in larvae collected during the 7-day sample.

Fall Egg Mass Survey

Each section of land infested with tussock moth, as determined by the 1973 fall egg mass survey, except those included in the *B.t.* field experiments conducted by the Pacific Northwest Forest and Range Experiment Station, also near Coeur d'Alene Mountain, was sampled for egg masses during September of 1974.

A total of 18 sections were sampled. Sampling consisted of felling five Douglas-fir or grand fir and removing four whole branches from each of three crown levels (lower, mid, top). All new and old egg masses and cocoons were counted on each branch. Five egg masses, when present, were collected, placed in paper bags, and returned to the laboratory for evaluation of natural virus, egg viability, and egg parasitism.

Of the 18 sections sampled, four met preestablished treatment criteria of 0.1 egg mass per 1,000 square inches of foliage (table 4).

A total of 34,138 acres qualified for treatment, based on egg mass density counts in the Coeur d'Alene Mountain unit in 1973 (see footnote 3). Based on the 1974 egg mass survey, less than 2,000 acres qualify for treatment in 1975. It is anticipated that evaluation of virus, egg viability, and egg parasitism will further reduce this acreage.

Table 1.--*Prespray Douglas-fir tussock moth levels, Selway test site, Nezperce National Forest, Idaho, June 24, 1974*

Block	Larvae per 1,000 in^2 foliage
Spray:	
Lookout Butte	3.14
Lodge Point	.87
Tahoe Ridge	7.35
Check:	
Tahoe #2	1.18
Corral Hill #1	2.77
Corral Hill #2	5.61

Table 2.--*Larval tussock moth population densities, Coeur d'Alene Mountain spray blocks, 1974. (Although spraying was aborted, population sampling was carried out as planned--to determine factors causing population decline)*

Plot	Date of sampling				Natural reduction prespray to 35-day
	Prespray 6/27-29	7-day, 7/3-12	21-day, 7/22-29	35-day 8/5-13	
	Larvae per 1,000 square inches of foliage				*Percent*
Virus I 301	Not sampled	0.8	0.7	0.1	87
Cottonwood Virus II *Bt*-801	7.0	3.2	.4	.1	99
Virus III-501	20.0	15.0	7.5	2.0	90
Turner *Bt*-401	45.0	12.2	2.9	.6	99
Beauty *Bt*-601	27.0	4.9	3.8	1.6	94
Pleasant *Bt*-701	16.0	3.5	3.2	1.5	91
Elk Mtn Check 1-80	1.8	.9	.2	.2	89
Beauty Check 101	6.0	1.2	.8	.3	95
Fortier Check 201	10.0	8.0	1.2	.4	96
Average					93

Table 3.--*Douglas-fir tussock moth mortality in nine spray blocks near Coeur d'Alene, Idaho, during summer of 1974*

Plot	Total collected	Percent mortality				
		Larvae dying of unknown causes	Emerged as adults	Hymenop-terous parasites	Dipterous parasites	Died of virus
Virus I	70	21.4	45.7	25.7	1.4	5.7
Cottonwood Virus II	320	33.7	52.2	10.3	.3	3.4
Virus III	1,371	38.4	49.9	5.9	3.2	2.6
Turner Bt.	1,235	43.9	43.2	7.5	.6	4.8
Beauty Bt.	1,695	31.6	54.3	10.8	.2	3.1
Pleasant Bt.	921	37.2	48.7	7.2	4.2	2.5
Elk Mountain Check	117	29.0	55.5	11.1	1.7	2.6
Beauty Check	239	33.5	48.9	15.5	0	2.1
Fortier Check	721	38.0	42.2	12.5	3.0	4.3
Total or Average	6,689	36.7	48.9	9.2	1.8	3.4

Table 4.--*Douglas-fir tussock moth egg mass densities, Coeur d'Alene Mountain, Idaho, September 1974*

Plot location, T. R. Sec.	1973 egg masses			1974 egg masses			Average egg mass density		Ratio, old: new
	Lower	Mid	Top	Lower	Mid	Top	1973	1974	
49N 2W 2	0.127	0.096	0	0.483	0.576	0.706	0.096	0.552	1:5.75
49N 2W 4	.037	0	.104	.037	0	0	.042	.014	1:.333
48N 2W 6	.057	.211	0	0	0	0	.11	0	1:0
49N 3W 7	0	0	.209	.03	0	0	.027	.013	1:481
49N 2W 8	.041	0	0	0	.035	0	.015	.015	1:1
49N 3W 14	0	0	0	0	.131	0	0	.057	1:0
49N 3W 15	0	0	.097	0	0	.194	.015	.029	1:193
49N 2W 17	0	.282	.792	.092	.169	.132	.233	.127	1:.545
49N 2W 19	.076	0	0	0	.046	0	.033	.017	1:.515
49N 2W 20	0	0	0	.083	.39	.225	0	.237	1:0
49N 3W 22	.063	.106	.261	0	.035	.131	.103	.03	1:.291
49N 3W 23	.029	.115	.213	0	.115	.107	.085	.057	1:.67
49N 3W 24	0	.281	.112	.07	.047	.112	.119	.068	1:.571
49N 3W 25	1.26	.961	.135	0	0	0	1.16	0	1:0
49N 3W 26	0	.652	.117	.054	.13	0	.232	.073	1:.314
49N 2W 29	0	.052	.149	0	.052	0	.041	.021	1:.512
49N 2W 32	0	0	0	0	.178	.331	0	.115	1:0
49N 3W 36	0	.112	0	0	.056	0	.047	.024	1:.511
Mean	.094	.159	.188	.0472	.109	.107	.131	.085	1:.649

STUDY NO. 5

PILOT CONTROL TEST OF SEVIN-4-OIL AND *BACILLUS THURINGIENSIS* AGAINST THE DOUGLAS-FIR TUSSOCK MOTH IN MONTANA - 1974

by

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INTRODUCTION

Ground surveillance activities in spring and summer, and aerial and ground surveys conducted in the summer of 1973, resulted in detection of approximately 350 acres of aerially visible defoliation by the Douglas-fir tussock moth, *Orgyia pseudotsugata* McDunnough, near Missoula, Montana. The principal landowner of the defoliated areas, located in the Worden Creek drainage near Lolo, and in the Albert and Rock Creek drainages near the Hoerner-Waldorf pulp and paper mill, was U.S. Plywood, Division of Champion International Corporation. Approximately 40 acres of the infested area near the mill was in U.S. Forest Service ownership, and about 80 acres of small private ownership was also involved. U.S. Plywood expressed considerable desire to control these localized spots while small, and we felt this was an excellent opportunity to evaluate effectiveness of insecticides other than DDT in a control program designed to minimize tussock moth impact in localized situations.

METHODS AND STUDY DESIGN

Two materials, Sevin-4-oil (carbaryl) and *Bacillus thuringiensis* (Berliner), were evaluated. Formulation of the Sevin-4-oil spray was two parts Sevin-4-oil plus one part No. 2 fuel oil. DuPont Oil Red Dye at 4 grams per gallon of spray was added. This provided for a dosage of 2 pounds of Sevin in 3/4 gallon total material per acre. Two 400-acre blocks, located in the Albert Creek and Rock Creek drainages near Frenchtown, were treated.

Formulation of the *Bacillus thuringiensis* (*B.t.*) spray was 1 pound of Dipel powder per 2 gallons of water plus Chevron Spray Spreader and Spray Sticker. Rhodamine B Extra Soluble S Dye was added at the rate of 4 grams per gallon of spray. Two gallons of total material were applied per acre to a 200-acre block near Lolo. A portion of the infested area in Albert Creek was left unsprayed to serve as a check.

Both materials were applied by a Bell 47G helicopter equipped with 8002 nozzle tips. The Sevin-4-oil blocks were sprayed June 14 and 15, and the *B.t.* block was sprayed June 25.

Sevin-4-oil was sprayed 3 days after 90 percent of 80 tagged egg masses (40 per spray block) had begun to hatch. Larvae were in first and second instars at this time. *B.t.* was sprayed when larval development had reached the following stages: first instar 5.8 percent, second instar 14.4 percent, third instar 40.4 percent, and fourth instar 39.4 percent.

Sample trees were Douglas-fir, 30 to 50 feet tall, and somewhat open grown. Fifty sample trees (10 five-tree clusters) were selected in each Sevin-4-oil block, 35 sample trees (seven five-tree clusters) were selected in the check area, and 36 single sample trees were selected in the *B.t.* area. Population samples were taken 24 hours before spraying and 7 and 14 days following treatment in the Sevin-4-oil areas. The *B.t.* area was sampled within 24 hours prespray and 7, 14, and 21 days postspray. Population samples were taken from two 18-inch branch tips clipped from opposite sides of each sample tree for each sample period. Larval populations were expressed as the number of larvae per 1,000 square inches of foliage.

Spray deposit was assessed from Print-flex cards located at ground level in openings, under the drip line of sample trees, and on elevated 20-foot poles.

Effect of spray treatment on foliage retention was evaluated by visually rating each sample tree prior to tussock moth feeding and again after feeding was completed. This was done by dividing the crown into six levels and assigning a numerical rating to each crown level according to the degree of defoliation. Ratings used were: 0 - negligible, 1 - light, 2 - moderate, and 3 - heavy. The six crown levels were weighted numerically 1 through 6 from top to bottom to represent the amount of foliage in each level. Crown level defoliation indexes were obtained by multiplying the defoliation rating by the crown level value. The defoliation index for the tree was obtained by adding the indexes of each crown level.

Egg mass surveys were made in the treatment areas in October 1974. A five-tree cluster was sampled per quarter-section by felling the trees and examining four whole branches from each of three crown levels. New egg masses, old egg masses, and cocoons were expressed as number per 1,000 square inches foliage.

RESULTS

Preliminary results indicate that Sevin-4-oil applied at the rate of 2 pounds in 3/4 gallon per acre reduced first-instar Douglas-fir tussock moth populations by 90.09 and 99.09 percent after 7 days and 95.86 and 99.44 percent after 14 days (table 1). Approximately 18 percent of the spray reached the target area. Spray deposit data are presented in table 3. Virtually no 1975 generation egg masses occurred in areas treated, as compared with an increase in egg mass deposits in the untreated check (table 5).

On the *B.t.* test, virtually no insect mortality was measured after 7 days, and a 73-percent reduction occurred after 14 and 21 days (table 2). Low rates of mortality may be due to the droplet size of the *B.t.* spray (> 400 microns VMD, table 3) and the fact that a commercial spreader-sticker, rather than molasses, was used.

Regression analyses were made on defoliation data to measure differences in feeding patterns among the various treatments and checks. Correlation coefficients (r) ranged from .661 to .832 (fig. 1) between prefeeding and postfeeding indexes for all treatments and checks, indicating that some influence of the prefeeding index was affecting the postfeeding damage index. This influence was due largely to SO^2 damage from the papermill to Douglas-fir foliage in the Sevin-4-oil treatment areas and the check area, and the previous year's tussock moth and spruce budworm defoliation in all the treatment areas. Because of this past influence it was difficult to correctly rate the sample trees for defoliation.

Means for prespray population, prefeeding index, and postfeeding index for the treatments and checks are listed in table 4. Postfeeding index means for both Sevin-4-oil treatments decreased, indicating that no further tussock moth damage occurred and the trees replaced some of the foliage previously lost to tussock moth feeding and SO^2 damage. The postfeeding index mean in the *B.t.* treatment increased, indicating that the 73-percent mortality due to spraying was not sufficient to avoid additional foliage loss. The decrease in the postfeeding index mean for the check area was probably due to the low population levels, which were not capable of causing noticeable defoliation, and the sample trees showed some recovery from previous SO^2 damage.

Covariance analysis of the data did not show significant difference in regression line slope between treatments and checks, probably due to SO^2 damage interference. Covariance analysis did show significant differences at the .05 level in both slope and intercept for the *B.t.* treatment when compared with the Sevin-4-oil treatments. This again indicates that feeding damage continued in the *B.t.* treatment but not in the Sevin-4-oil treatment areas.

Egg mass densities decreased in treatment areas and increased slightly in the check block (table 5).

OPERATIONAL PROBLEMS

Consistent nozzle plugging was experienced during the aerial application of Sevin. Nozzles were plugged with a material the consistency of sand. It was not determined if this was due to the Sevin-4-oil or the addition of the dye.

Table 1.--*Summary of pretreatment and posttreatment Douglas-fir tussock moth population densities, Sevin-4-oil pilot control project, western Montana--1974*

Plot location and sample	Number of sample trees	Prespray density[1/]	Postspray density[1/]	Survival ratio	Corrected percent control[2/]
Albert Creek:					
1st postspray 6-21-74	50	89.58	0.57	0.0064	99.09
2nd postspray 6-28-74	50	89.58	.27	.0030	99.44
Rock Creek:					
1st postspray 6-22-74	50	78.68	5.49	.0698	90.09
2nd postspray 6-28-74	50	78.68	1.73	.0220	95.86
Check:					
1st postspray 6-25-74	35	7.41	5.22	.7045	
2nd postspray 7-2-74	35	7.41	3.94	.5317	

1/ Larvae per 1,000 square inches of foliage.

2/ Corrected using Abbott's formula $Y = 1 - \frac{(TAA \times CAB)}{(TAB \times CAA)}\ 100.$

Y = percent control, TAB = prespray population treatment mean, TAA = postspray population treatment mean, CAB - prespray population control mean, and CAA = postspray population control mean.

Table 2.--*Summary of pretreatment and posttreatment Douglas-fir tussock moth population densities,* Bacillus thuringiensis *pilot control project, western Montana--1974*

Plot location and sample	Number of sample trees	Prespray density1/	Postspray density1/	Survival ratio	Corrected percent control2/
Worden Creek:					
1st postspray 7-2-74	36	57.01	42.29	0.7418	1.72
2nd postspray 7-9-74	36	57.01	22.31	.3913	73.44
3rd postspray 7-16-74	36	57.01	17.05	.2991	73.31
Check:					
1st postspray 7-2-74	35	5.22	3.94	.7548	
2nd postspray 7-9-74	35	5.22	7.69	1.4732	
3rd postspray 7-16-74	35	5.22	5.85	1.1207	

1/ Larvae per 1,000 square inches of foliage.

2/ Corrected using Abbott's formula $Y = 1 - \frac{(TAA \times CAB)}{(TAB \times CAA)}\ 100.$

Y = percent control, TAB = prespray population treatment mean, TAA = postspray population treatment mean, CAB = prespray population control mean, and CAA = postspray population control mean.

Table 3.--*Summary of spray deposit data from Print-flex card analysis,*1/ *Sevin-4-oil and* Bacillus thuringiensis *pilot control project, western Montana--1974*

Card location and treatment	Number of cards processed	Volume median diameter drop (microns)	Deposition density of mixture (gal/acre)
Worden Creek - *B.t.*			
Under tree north	35	408	0.4740
Under tree south	36	425	.7618
Open	71	431	1.0358
Rock Creek - Sevin-4-oil			
Under tree north	48	224	.1084
Under tree south	49	237	.1550
Open	97	237	.1688
20-foot poles	24	230	.1550
Albert Creek - Sevin-4-oil			
Under tree north	50	225	.1411
Under tree south	50	234	.1399
Open	100	230	.1499
20-foot poles	24	208	.1147

1/ Print-flex card analysis by Deseret Test Center, Department of Defense, Dugway, Utah.

Table 4.--*Means for prespray population and prefeeding and postfeeding defoliation indexes, Sevin-4-oil and* Bacillus thuringiensis *pilot control project, western Montana--1974*

Plot location and treatment	Prespray population[1/]	Prefeeding index	Postfeeding index
Albert Creek (Sevin-4-oil)	89.58	25.20	10.00
Rock Creek (Sevin-4-oil)	78.68	9.62	4.34
Worden Creek (*Bacillus thuringiensis*)	57.01	30.30	38.44
Albert Creek			
(Sevin-4-oil check)	7.41	6.34	3.22
(*Bacillus thuringiensis* check)	5.22	6.34	3.22

1/ Number of larvae per 1,000 square inches of foliage.

Table 5.--*Egg mass densities in treatment and check blocks in the fall of 1974, following treatment*

Plot location and treatment	Density of new egg masses 1/	Density of old egg masses 1/	Ratio of old to new egg masses
Albert Creek (Sevin-4-oil)	0.000	0.270	1 to 0
Rock Creek (Sevin-4-oil)	.004	.347	1 to 0.01
Worden Creek (*Bacillus thuringiensis*)	.090	.269	1 to 0.33
Check	.057	.043	1 to 1.33

1/ Number per 1,000 square inches of foliage.

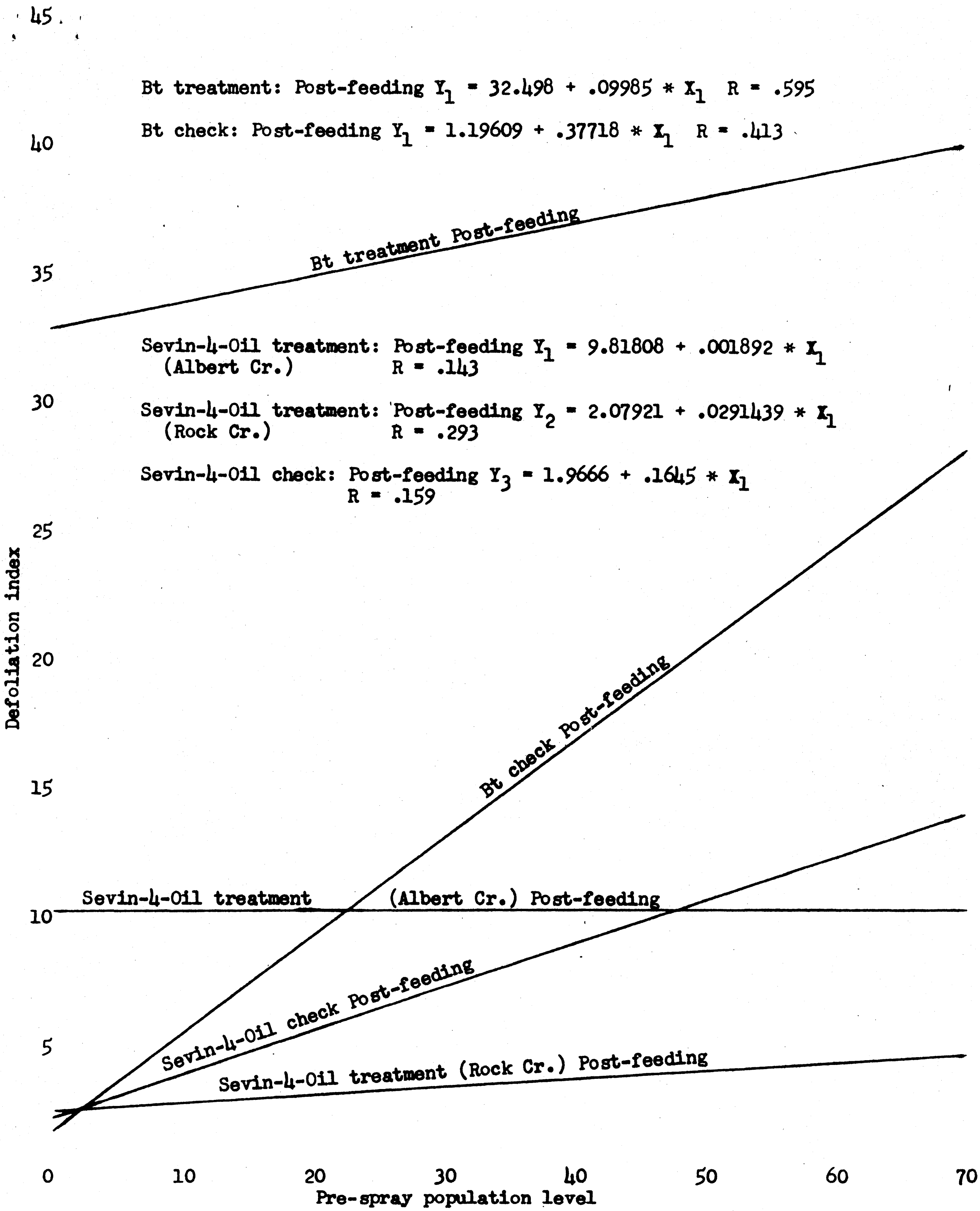

Figure 1. Regression analysis of Sevin-4-Oil treatments, Bacillus thuringiensis treatment, and checks.

STUDY NO. 6

FIELD EXPERIMENT OF SEVIN-4-OIL, DYLOX, AND DDT ON DOUGLAS-FIR TUSSOCK MOTH NEAR HALFWAY, OREGON - 1974

by

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INTRODUCTION

Two insecticide formulations, Sevin-4-oil (carbaryl) and Dylox 1.5 (trichlorfon), are believed by Forest Service entomologists to have promise for control of Douglas-fir tussock moth (DFTM). These chemicals were field tested in 1973. Results of those tests indicated the need for further investigations of these materials, which was undertaken in 1974.

OBJECTIVES

The primary objective was to determine and compare the effects of Sevin-4-oil, Dylox 1.5, and DDT formulations applied 4 days after 70 percent of the egg masses had started to hatch on:

1. Immediate suppression and subsequent generation survival of DFTM populations.

2. Preservation of the new (current year's) foliage.

EXPERIMENTAL DESIGN

The four treatments were:

Treatment	Majority instar at treatment	Dosage (lb)	Volume (per acre)	Droplet size (microns)	Nozzle size	Pressure (psi)
DDT[1/]	1	0.75	1 gal	200-500	8002	40-50
Dylox 1.5	1	1.0	5.3 pt	300-350	8002	40-50
Sevin-4-oil	1	1.0	1/4 gal	300-350	8002	40-50
Check	1	--	--	--	--	--

[1/] 0.75 lb DDT solution dissolved in 1 gal. fuel oil. The other insecticides were applied undiluted.

The four treatments were replicated three times on 12 60- to 80-acre study plots located in the three areas set aside for these field tests. Twelve study plots were arranged into three groups of four plots each, corresponding to the three areas, using a randomized block statistical design.

STUDY PROCEDURE

After the study plots were established, approximately 40 egg masses were collected from each plot for larval rearing and subsequent virus determination. Forty trees divided into four clusters of 10 trees each were located in each study plot for DFTM population sampling and foliage assessment. Treatment applications began 4 days after 70 percent DFTM egg hatch. DFTM larval populations on each tree were sampled 24 hours before treatment and at 4 and 14 days following treatment. Collections of larvae were made during these sampling periods for virus determination. Treatment effects were evaluated in two ways: (1) foliage preservation and (2) population suppression. Foliage preservation is indicated by the percent of shoots (new foliage) affected by DFTM feeding. DFTM population density estimates for indicating population suppression were made by two methods. First, by determining the number of larvae before and after treatment per 1,000 in^2 of foliage; and second, by determining the number of larvae per 100 shoots. Population densities based on 100 shoots should have closer correspondence to foliage damage in the new leaves than population densities based on 1,000 in^2 of branch surface.

Preliminary Results

Results of the field tests were heavily influenced by virus which was widespread in DFTM populations at the Halfway Unit. An incidence of 40 percent virus in the hatching larvae was estimated for this area by the spring egg mass collection and rearing study. These data were verified by the egg masses collected at each study plot and larval collections made during each population sampling period (tables 1 and 2). This indicated high mortality among the hatching larvae. As a result, the prespray populations were very low and highly variable from cluster to cluster and plot to plot.

A preliminary examination of the data shows some treatment effects in spite of low initial populations (table 1).

Within the limits of sampling, all DDT applications reduced the 4-day postspray population densities to zero. However, there was no significant difference between percent control obtained for Sevin and Dylox and the checks ($P = .05$). At 14 days after spraying, there were statistical differences for Sevin and Dylox on larval populations per 1,000 in^2 of branch surface. Both materials significantly reduced populations as compared with the checks. Neither, however, was as effective as DDT. The

data show that Dylox was superior to Sevin, but the difference is not statistically significant at the P = .05 level. Except for DDT, analyses on larval populations per 100 shoots were not significant for both the 4-day and 14-day data.

Effectiveness of each treatment was influenced by the quality of application of insecticides, the volume applied, and the droplet sizes used (table 3). The DDT treatment provided the best coverage, averaging 0.121 gallon per acre (GPA) and 11.6 droplets per square centimeter on the spray plates and cards. Dylox treatments gave the next best coverage, afteraging 0.115 GPA and 4.2 droplets per square centimeter. Sevin-4-oil had the poorest coverage, with an average of 0.032 GPA and 1.6 droplets. The same nozzle size (8002) and spray pressure (40 to 50 PSI) were used in applying all materials. Differences in viscosity produced different droplet sizes. Droplet size was smallest for DDT. Droplet size spectra for Sevin-4-oil and Dylox were similar. The VMD's averaged 133, 287, and 281 microns for DDT, Dylox, and Sevin-4-oil, respectively.

Table 1.--Prespray and postspray DFTM population densities, percent foliage damage, and virus incidence on egg masses associated with study plots and treatments

Treatment and plot	Virus incidence		Population reduction							Percent shoots affected		
	No. egg masses sampled	Percent of larvae with virus at 14-day postspray	DFTM/1,000 in^2 foliage			DFTM/100 shoots				Pre spray	Postspray	
			Pre spray	Postspray 4-day	Postspray 14-day	Pre spray	Postspray 4-day	Postspray 14-day			4-day	14-day
Check:												
1	40	31.2	0.05	0.01	0.01	0.52	0.28	0.13		21.9	27.5	--
7	41	14.2	.07	.03	.03	.79	.69	.98		1.4	7.4	
10	41	6.6	.17	.06	.04	1.69	1.32	.90		4.9	11.7	34.7
	Average percent natural decline			67.3	71.2		26.2	32.6	Average	9.1	15.6	--
DDT:												
2	42	32.0	.12	0	0	1.28	0	0		15.13	15.75	--
5	41	14.2	.27	0	0	2.62	0	.02		1.39	7.45	--
8	40	27.5	.13	0	0	1.19	0	0		3.33	5.16	9.85
	Average percent control			100	100		100	99.7	Average	6.62	9.13	--
Sevin-4-oil:												
3	47	41.2	.15	.02	.01	1.60	.38	.14		15.26	20.23	--
6	39	31.9	.12	.06	.03	1.35	1.53	.69		.43	9.80	--
11	52	6.1	.11	.04	.02	1.46	.87	.40		11.02	21.38	21.38
	Average percent control			66.8	83.4		34.4	70.9	Average	8.24	17.14	--
Dylox:												
4	36	4.9	.04	0	.01	.49	.07	.12		1.28	3.83	--
9	37	20.2	.05	.01	0	.51	.20	.02		2.22	6.51	12.15
12	26	27.6	.02	.01	0	.25	.09	.03		9.52	10.49	--
	Average percent control			76.7	91.7		70.2	86.5	Average	4.34	6.94	--

Table 2.--*Virus incidence in larval collections made during each sampling period*

Treatment and plot	Prespray			4-day postspray		
	Total no. larvae collected	Percent of larvae with virus at 14 days	Percent of larvae with virus at 21 days	Total no. larvae collected	Percent of larvae with virus at 14 days	Percent of larvae with virus at 21 days
Check:						
1	20	55.0	55.0	18	16.7	16.7
7	28	42.9	42.9	41	2.4	2.4
10	62	37.1	37.1	67	9.0	10.4
DDT:						
2	55	40.0	43.6	--	--	--
5	--	--	--	--	--	--
8	68	33.8	33.8	--	--	--
Sevin-4-oil:						
3	56	51.8	51.8	21	23.8	23.8
6	44	45.5	45.5	73	47.9	47.9
11	49	16.3	16.3	54	29.6	33.3
Dylox:						
4	15	40.0	40.0	5	40.0	40.0
9	30	26.7	26.7	15	26.7	26.7
12	10	50.0	50.0	5	20.0	40.0

Table 3.--*Deposit data for field experiment of Sevin-4-oil, Dylox, and DDT near Halfway, Oregon - 1974*

Treatment and plot	Deposit on spray plates and cards			
	Volume (gal/acre)	Percent recovery	Drops per cm^2	VMD (μ)
DDT:				
2	0.150	15.0	13.1	142
5	.074	7.4	9.1	123
8	.140	14.0	12.6	133
Average	.121	12.1	11.6	133
Dylox:				
4	.176	26.2	6.0	277
9	.104	15.7	4.1	319
12	.064	9.7	2.4	265
Average	.114	17.2	4.17	287
Sevin-4-oil:				
3	.020	8.0	1.2	221
6	.036	14.4	2.2	360
11	.041	16.4	1.3	363
Average	.032	12.9	1.57	281

STUDY NO. 7

PILOT TEST OF DYLOX 1.5-OIL, SEVIN-4-OIL, AND DDT AGAINST THE DOUGLAS-FIR TUSSOCK MOTH IN OREGON--1974

by

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Denver, Colorado

INTRODUCTION

This pilot control project was undertaken to determine the efficacy of aerial applications of carbaryl (Sevin-4-oil) and trichlorfon (Dylox 1.5-oil) for the control of the larvae of the Douglas-fir tussock moth.

The project was organized in late May with the expectation that spraying might begin as early as the first or second week in June. A Project Work Plan was prepared by George Downing and Thomas Flavell who were detailed to the Project as Project Leader and Assistant Project Leader, respectively. The plan was approved by the Regional Forester, Region 6, and the PNW Station Director on May 31, and the WO on June 4.

All tests were conducted in the vicinity of Halfway, Oregon.

METHODS AND STUDY DESIGN

Test Treatments

1. Sevin-4-oil (Carbaryl) applied at the rate of 2 pounds active ingredient per gallon per acre.

2. Dylox 1.5-oil (Trichlorfon) applied undiluted at the rate of 1 gallon per acre (1.5 pounds active ingredient per acre).

3. DDT applied at 0.75 pounds active ingredient per gallon per acre.

4. Untreated control.

Diesel oil was the carrier for Sevin-4-oil and DDT.

Test Design and Plot Size

The test design consisted of three treatments and an untreated control, each replicated three times, for a total of 12 test plots. Plot sizes ranged from 434 to 1,134 acres. The DDT plots were selected

in an area scheduled for operational spraying, and the untreated control plots were selected in areas that offered a good buffer from any of the chemical treatments and that would not be viewed from roads used by the public. The plots treated with Dylox 1.5-oil and Sevin-4-oil were chosen randomly.

Sampling

Five samping procedures were carried out to meet the test objectives: (1) virus incidence; (2) egg hatch occurrence for timing of spray applications; (3) tussock moth larval population and damage to foliage; (4) spray deposit; and (5) fall egg mass deposition.

Virus incidence.--Eighty egg masses were collected per plot by personnel assigned to the operational project; masses were flown to the Forestry Sciences Laboratory in Corvallis, Oregon, for rearing and analysis.

Egg hatch.--Egg hatch plots were established in each test plot by personnel from the operational DDT project. The date of spraying for all plots was determined on the basis of the same criteria as used in the operational DDT project--3 days after 70 percent of the sample egg masses began hatching. Actual spraying of the nine treatment plots was done from June 24 through July 8.

Tussock moth larval population sampling and assessment of foliage protection.--Both population and foliage assessment determinations were made from 16 clusters of five trees each from each test plot. From each sample tree, two prespray, 18-inch branch samples and four postspray, 18-inch branch samples were taken. Prespray samples were taken within 72 hours of spray application, and postspray samples were taken at 4 and 21 days after spraying. The number of tussock moth larvae present on each branch was recorded as well as the number of damaged and undamaged needles on samples of the new foliage. All sampling was done under contract with the Lake Ontario Environmental Laboratories (LOTEL), State University of New York, Oswego, New York. As part of the contract, LOTEL will prepare a report with appropriate statistical analysis, showing differences in treatment effects on larval survival and foliage damage, correlations between larval survival after treatments and the fall egg mass counts, larval survival and spray droplet size, and larval survival and spray deposit. These analyses are not yet available for inclusion in this report.

Spray deposit.--The work plan called for use of oil red dye; however, the first batch of Sevin-4-oil that was mixed with this material showed evidence of a contaminant in the dye. Oil red dye was eliminated from the remaining batches of chemicals that were mixed, with the exception of the DDT plots where a larger nozzle size was used and clogging was not a problem. Oil-sensitive red cards were used on the remaining plots, with the exception of one Dylox plot where Rhodamine B (a red dye) was used with white cards.

Fall egg mass deposition.--After egg laying was completed, four whole midcrown branches from the cluster sample trees were removed and examined for new egg masses. This work was also done by LOTEL under contract. At the time of initial selection of cluster trees by LOTEL, six crown levels of each tree were rated and placed into one of four defoliation classes. This was done prior to any larval feeding. These same trees were re-rated in the same manner by LOTEL at the time the fall egg mass samples were obtained.

Pesticide Application

The Dylox and Sevin plots were sprayed with a Hiller SL-3 helicopter. Contractual procedures were the same as for the DDT operational project.

The helicopter was equipped with a 48-foot spray boom and 50 size-8002 nozzles facing straight down. Nozzles facing 45 degrees down and forward were preferable, but the fittings could not be obtained in time for the start of spraying. This increased the spray droplet size somewhat, but it was not considered serious.

Dr. George Markin, Aerial Applications Project Leader, served as technical advisor on calibration of the helicopter and on aerial application. Technical representatives from the chemical companies producing the materials used were available for consultation during the initial phases of the spraying. Dr. Brian Cheary was the principal representative for Union Carbide (Sevin), and Dr. Connie Garner the principal representative for Chemagro (Dylox).

RESULTS

The results in this report are preliminary, as the data have not been completely analyzed by the contractor (LOTEL).

Table 1 summarizes virus incidence data from the egg masses collected in June 1974, before application of the insecticides. A total of 13,100 larvae were reared and 4,781, or 36.5 percent, were infected with the virus disease.

Table 2 summarizes Douglas-fir tussock moth larval populations on treated and untreated plots both before and after spraying. Larval populations during the prespray sample ranged from 0.5 to 11.4 larvae per 1,000 square inches of foliage. The average percent control for the three Dylox plots was 70.0 at 4 days after spraying, and 83.1 at 21 days. For the three Sevin plots, percent control averaged 53.0 at 4 days and 89.5 at 21 days. DDT resulted in 100 percent mortality of tussock moth larvae by 4 days.

Spray deposit data are summarized in table 3. Although there were some mechanical problems, primarily plugged nozzles during spraying, the coverage at ground surface was adequate for most plots.

Table 4 summarizes the percent of damaged needles on the sampled current year's foliage for all plots both before and after treatment.

No new egg masses were found on any sample branches from sprayed or unsprayed plots during the final fall examination.

Total tree defoliation class data were received too late for inclusion in this report.

GENERAL OPERATIONAL-USE CONSIDERATIONS

Dylox 1.5-oil presented no problems in handling. It was pumped directly from the drums with ease and flowed smoothly with no plugging of nozzles.

Sevin-4-oil varied considerably in viscosity from drum to drum and was difficult to pump with the equipment available at the site. Considerable plugging of in-line screen and nozzles was encountered. This problem was due in part to contaminants in the dye and diesel oil that were added during the mixing. Contaminants were also present in the Sevin-4-oil as evidenced by plugging of the in-line screen when pumping directly from the drums into the tank truck.

Table 1.--*Virus incidence, Pilot Control Project, Halfway, Oregon, June 1974*

Treatment	Location		Number of egg masses:			Number of larvae:		Percent virus incidence
	T., R.	Sec.	Collected	Hatched	With virus	Reared	With virus	
Dylox 1.5	6S, 47E	30	50	41	32	775	288	37.16
	6S, 47E	33	80	4	2	52	3	5.77
Sevin-4-oil	6S, 47E	16	78	69	63	1,218	549	45.07
	6S, 47E	11,12	80	70	55	1,256	556	44.27
	6S, 47E	28,29	80	67	57	1,112	577	51.89
	6S, 47E	9,10	79	64	44	930	442	47.53
DDT	5S, 47E	26	80	62	55	1,328	443	33.36
	5S, 47E	27,28	80	70	64	1,597	522	32.69
	5S, 47E	35	80	74	44	1,417	252	17.78
Check	6S, 47E	14	80	74	58	1,196	473	39.55
		15	77	13	11	200	76	38.00
		21	80	23	18	356	70	19.66
		29	79	76	54	1,364	394	28.89
		29	80	22	21	299	136	45.48
	Total		1,083	736	578	13,100	4,781	36.50

Table 2.--*Effectiveness based on insect counts, Pilot Control Project, Halfway, Oregon, June 1974*

Treatment and plot	Larvae per 1,000 in^2 foliage			Percent control 1/	
	Prespray	4-day postspray	21-day postspray	4-day postspray	21-day postspray
Dylox:					
Fox	7.02	1.83	0.48		
Pole	1.72	.58	.11		
Sheep	2.29	.12	.14		
Mean	3.68	.85	.24	70.0	83.1
Sevin-4-oil:					
Driveway	5.97	2.41	.33		
Dutchman	2.79	.46	.08		
U. Fall	5.39	1.15	.05		
Mean	3.70	1.34	.15	53.0	89.5
DDT:					
DDT-1	7.93	0	0		
DDT-2	2.93	0	0		
DDT-3	.51	0	0		
Mean	3.79	0	0	100	100
Check:					
Big Elk	3.07	3.53	1.24		
Corral	11.36	8.03	5.68		
Jolly	9.93	7.22	2.49		
Mean	8.12	6.26	3.13		

1/ Calculations based on Abbott's formula: Percent control = $1-\frac{TA \times CB}{TB \times CA} \times 100$, TA = the number of live insects per 1,000 square inches of foliage sampled on the treated area after treatment. TB = the number of live insects per 1,000 square inches of foliage sampled on treated area before treatment. CA = the number of live insects per 1,000 square inches of foliage sampled on check area after treatment. CB = the number of live insects per 1,000 square inches of foliage sampled on check area before treatment.

Table 3.--*Spray deposit data, Pilot Control Project, Halfway, Oregon, June 1974*

Treatment and plot	Coverage		
	Drop size (VMD) (μ)	Drop density (No./cm^2)	Gal/acre
Dylox:			
Fox	424	7.29	0.278
Pole	467	3.87	.410
Sheep	424	3.44	.105
Sevin-4-oil:			
Driveway	508	8.89	.144
Dutchman	284	24.45	.580
U. Fall	276	16.04	.192
DDT:			
DDT-1	352	1.56	.360
DDT-2	305	4.97	.538
DDT-3	353	6.74	.686

Table 4.--*Percent of current year's foliage damaged by defoliating insects, Pilot Control Project, Halfway, Oregon, June 1974*

Treatment and plot	Percent of current year foliage damaged at:		
	Prespray	4-day postspray	21-day postspray
Dylox:			
Fox	1.9	1.5	3.4
Pole	1.2	3.1	4.7
Sheep	1.1	4.3	3.7
Total	1.4	3.0	3.9
Sevin-4-oil:			
Driveway	2.6	1.3	1.1
Dutchman	1.8	1.4	3.6
U. Fall	1.3	1.7	6.0
Total	1.9	1.5	3.6
DDT:			
DDT-1	1.6	2.3	5.0
DDT-2	1.3	1.3	3.8
DDT-3	.9	1.7	4.4
Total	1.3	1.8	4.6
Check:			
Big Elk	2.3	1.2	4.4
Corral	2.1	1.3	6.7
Jolly	2.8	2.5	1.2
Total	2.4	1.7	4.1

Note: These data have not been analyzed to determine if any real statistical differences exist. Differences do not seem significant.

STUDY NO. 8

PILOT CONTROL TEST OF SEVIN-4-OIL AGAINST THE DOUGLAS-FIR TUSSOCK MOTH IN IDAHO - 1974

by

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INTRODUCTION

In its continuing program to find suitable alternatives for Douglas-fir tussock moth control, the U.S. Forest Service conducted a pilot test of the carbamate insecticide, Sevin-4-oil, in 1974 in Idaho.

Two units of approximately 650 acres each were sprayed with 2 pounds per acre of Sevin-4-oil in sufficient fuel oil to make three-fourths of a gallon. Spray units were located on lands owned by Potlatch, Inc., near Potlatch, Latah County, Idaho. An untreated check was located near Boundary Point.

METHODS

Test design.--The sample size was based on data from a 1973 Sevin-4-oil test in Idaho. The following sampling design was decided upon: two branches per tree, five trees per cluster, and 16 clusters per area. The test was restricted to two spray blocks and one check block by the availability of good test sites and insecticide. Sample trees were open-grown Douglas-fir and grand fir, 20 to 50 feet in height. Branch samples were collected from the middle one-third of the crown, using telescopic pole pruners with catch baskets attached.

Assessing foliage retention.--Each sample tree was rated as to its degree of defoliation a day before the areas were sprayed. This was done by dividing the crown into six levels and assigning a numerical rating for each crown level, depending on the degree of defoliation: 0 = negligible, 1 = light, 2 = moderate, and 3 = heavy. The crown levels were weighted numerically to represent amount of foliage in that crown level: top one-sixth - 1, next one-sixth - 2, and bottom one-sixth - 6. A defoliation index for each crown level was obtained by defoliation-rating X crown level. A defoliation index for the tree was arrived at by summing the defoliation indexes of each crown level. A regression analysis was made plotting the defoliation index over the prespray population level to give a prediction of the amount of defoliation that could be expected without the treatment. This was then

compared to the total defoliation that actually existed. The difference was attributed to treatment. Covariance analysis was used to test differences between regression of postfeeding evaluation.

Population sampling schedule.--A prespray population sample was collected within 48 hours of spraying. Two postspray samples were collected 7 days and 14 days after spraying.

Processing samples.--All samples were processed in the field. A 3-man crew pruned the branches, placed them on a tarp, measured branch length and width, and counted all tussock moth larvae.

Insect development determination.--Instar determinations were made visually by an entomologist during the prespray sample. A prepared instar identification sheet listing the conspicuous characteristics of each instar was used.

Insecticide application.--Two pounds of Sevin-4-oil in enough fuel oil to make three-fourths gallon per acre was applied with a Bell 205 helicopter. The helicopter was equipped with 27 No. 8010 T Jet Spray Systems, Inc., spray tips directed 45 degrees forward to the thrust lines of the aircraft. A boom pressure of about 40 pounds per square inch was maintained during spraying. Spraying was done at a flying speed of 90 miles per hour.

Deposit assessment.--The amount of insecticide reaching the ground in spray areas was determined by placing two oil-sensitive spray deposit cards near each sample tree. Spray deposit cards were read by the U.S. Department of Defense, Deseret Test Center, Dugway, Utah. Percent spray reaching the ground and VMD of the droplets were determined.

Treatment effect determination.--The percent population reduction was determined by comparing postspray counts with prespray counts and correcting this value for natural mortality using a modified version of Abbott's formula.

Fall egg mass survey.--An egg mass survey was made in the study areas in late September of 1974. Four 5-tree clusters were sampled in each area by felling the trees, dividing the crown into thirds, and examining four whole branches per crown level for new egg masses, old egg masses, and cocoons. Branches were measured and converted to square inches of foliage. Number of egg masses per 1,000 square inches of foliage was computed.

RESULTS

Treatment effect on target insect.--Spray was applied July 11. Larval development at that time was 3 percent, 60 percent, and 37 percent respectively in second, third, and fourth instars. Percent population reduction corrected for natural mortality is shown in table 1.

Spray deposit.--The average mass median diameter of the spray droplets reaching the ground was 105.98 microns for spray area 1 and 130.32 microns for spray area 2. The data are still being analyzed to determine the deposit reaching the ground.

Effect of treatment on defoliation.--A regression analysis showed that the treatment reduced expected defoliation about 50 percent (fig. 1). A covariance analysis showed the regression lines were different at the 95-percent level of confidence. The covariance analysis also showed no difference in the regression lines of the two sprayed areas.

Egg mass survey.--The egg mass survey showed that low egg mass levels currently exist in all three areas (table 2).

OPERATIONAL PROBLEMS

Problems were found in the mixing, formulating, and spraying of the insecticide, but these were mostly mechanical and can be corrected. Some problems encountered were:

1. Considerable variation existed in the Sevin-4-oil formulation. Two drums had virtually solidified and could not be used. The material had previously been stored for about a year, which may have caused the problem.

2. Because of the viscosity of the Sevin-4-oil, we had difficulty pumping from the drums into the mixing tank with a centrifugal pump. A positive displacement pump is needed.

3. The spray mixture is a milky white color. This caused vision problems for the spray pilot when it accumulated on the helicopter bubble. The pilot was forced to fly each swath updrift from the previous swath to avoid this hazard.

Table 1.--*Population reduction by sample period*

Treatment and area	Prespray population density[1]	7-day postspray population density[1]	14-day postspray population density[1]
Sevin-4-oil			
Block 1	20.53	3.11	0.281
Block 2	50.71	5.58	.960
Check	16.55	14.88	7.020
		Percent control[2]	
Block 1		83.15	96.770
Block 2		87.76	95.53

[1] Larvae on 1,000 square inches of foliage.

[2] Calculations of percent reduction in spray blocks based on Abbott's formula:
Percent control = $1 - \frac{TA \times CB}{TB \times CA} \times 100$. TA = the number of live insects per 1,000 square inches of foliage sampled on the treated area after treatment. TB = the number of live insects per 1,000 square inches of foliage sampled on treated area before treatment. CA = the number of live insects per 1,000 square inches of foliage sampled on check area after treatment. CB = the number of live insects per 1,000 square inches of foliage sampled on check area before treatment.

Table 2.--*Egg mass densities for Sevin-4-oil Pilot Control Project, Potlatch, Idaho*

Treatment and area	Egg mass density/1,000 in^2 foliage		New to old egg mass ratio
	Fall 1974	Fall 1973 1/	
Sevin-4-oil:			
1	0.008	0.244	1:29
2	.005	.261	1:52
Check:			
3	.014	.345	1:24

1/ Computed by identifying all old egg masses found in September 1974 as 1973 egg masses.

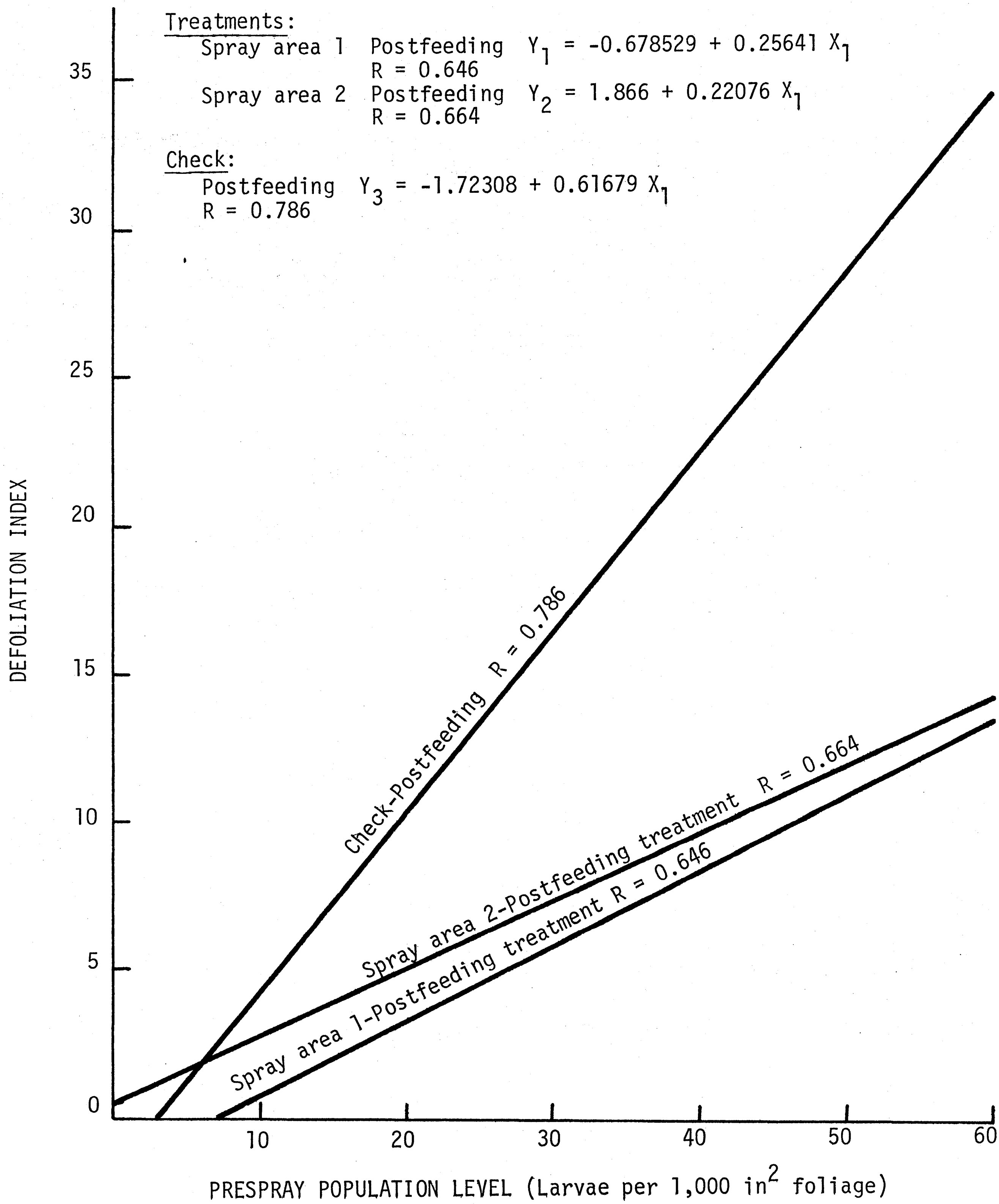

Figure 1.--Regression analysis showing differences in defoliation intensity as a result of treatment with Sevin-4-oil.

Field tests involving aerial applications of new *B.t.* formulations were carried out near Coeur d'Alene, Idaho, in 1974. A description of these tests is presented in Appendix, Study No. 3.

1974 pilot control tests.--A large-scale pilot control project of *B.t.* and virus was planned for two test sites in northern Idaho in 1974. When tussock moth populations failed to develop as expected, these tests were aborted. These tests were well advanced; consequently, several findings could be useful in future testing. Problems encountered in formulation of the microbial sprays, insect population data, and potential for damage in 1974 in the affected area are presented in Appendix, Study No. 4. *B.t.* was applied to one 200-acre plot in a pilot control test conducted by the Montana Division of Forestry near Missoula. The results of this test are given in Appendix, Study No. 5.

C. Chemical Insecticides

1. Sevin-4-oil (carbaryl) and Dylox (trichlorfon).--A number of field experiments and pilot control projects using these compounds were conducted in 1973 and 1974 in Idaho, Montana, and Oregon by the U.S. Forest Service and cooperating State agencies. These include:

Field experiment of Sevin-4-oil, Dylox, and DDT in Oregon (Appendix, Study No. 6).

Pilot test of Dylox 1.5-oil, Sevin-4-oil, and DDT in Oregon (Appendix, Study No. 7).

Pilot test of Sevin-4-oil in Montana (Appendix, Study No. 5).

Pilot test of Sevin-4-oil in Idaho (Appendix, Study No. 8).

Pilot test of Dylox in Oregon (Appendix, Study No. 9).

These projects are in various stages of completion. Preliminary results are reported in the above referenced studies.

2. DDT--In accordance to the EPA Order, four replicated tests were carried out to more precisely determine the effectiveness of DDT. These were: (1) the reduced DDT dosage helicopter test, using 1/4-, 1/2-, and 3/4-pound per acre (Appendix, Study No. 10); (2) the field tests of Sevin-4-oil, Dylox, and DDT (Study No. 6); (3) the pilot control helicopter test of Sevin-4-oil, Dylox, and DDT (Study No. 7); and (4) the individual tree screening tests using a number of other insecticides (Study No. 11). Results of this year's tests are presented in the Appendix.

3. Other insecticides.--In addition to the specific 1974 field testing of chemical and microbial insecticides described above, the Forest Service has screened many materials in the laboratory and conducted numerous ground and aerial field tests against the Douglas-fir tussock moth. This work is summarized in Studies 11 and 12.

Laboratory tests: Laboratory tests on contact toxicity showed the following compounds to be more toxic to fourth-instar larvae than was DDT at LD_{50} (shown in decreasing order of effectiveness): BEM, resmethrin, pyrethrins, chlorphoxim, methomyl (Lannate) and Folaton. The following were not statistically different from DDT in toxicity: chlormethylfox, Phosvel, Zectran, and Methoxychlor. DDT was about 31 times more toxic than Orthene.

Largon (TH-6040), an insect growth regulator, showed 90 percent mortality at 0.1 ppm when formulated in the larval diet.[1/] When applied to potted trees on which larvae later fed, a level of 90 percent mortality was reached with a dosage equivalent to 0.125 ounce per acre (0.0078 pound per acre).

Ground experiments by backpack sprayer: Several insecticides were tested by a field screening technique designed to simulate aerial application. Data are summarized in Appendix, Study No. 11.

Aerial field experiments: Zectran was not tested in 1974 because commercial production had been discontinued.[2/]

In 1974, Orthene was tested on 20-acre plots in Oregon at 1/2 and 1 pound per 2 gallons of water per acre (see Appendix, Study No. 12). Sprays were applied 4 to 5 days after 100 percent egg hatch (most larvae were in second instar).

D. Other Research

Research on sex attractant.--Significant progress was made during 1974 in the area of population detection. In cooperation with chemists at the Oregon Graduate Center in Beaverton, Oregon, Forest Service research entomologists isolated and identified the chemical structure of the sex pheromone of the tussock moth. This compound, (E) - 6 - heneicosen - 11 - one, has been synthesized and successfully field tested. Traps baited with microgram quantities of this material provide a sensitive detection method. (See Appendix, Study No. 13.)

1/ Gillette, N., *et al.* Bioassays of Largon against selected forest defoliators (manuscript in preparation).

2/ Correspondence from Robert P. Harrison, Development Specialists, Dow Chemical Co., June 1974.

STUDY NO. 1

POPULATION DYNAMICS AND IMPACT OF THE DOUGLAS-FIR TUSSOCK MOTH

by

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INTRODUCTION

Investigations of the dynamics and impact of tussock moth populations have been underway at the Pacific Northwest Forest and Range Experiment Station for a number of years. Several outbreaks in the West have been studied and patterns of population change, natural mortality factors, and tree damage recorded.[1/] [2/] [3/]

To collect additional information on natural population behavior, new investigations were initiated in the Blue Mountains in 1971 and early 1972 before the full extent of the impending outbreak was known. These included population monitoring activities, as well as detailed field studies on food consumption by tussock moth larvae. With the advent of an extensive outbreak in mid-1972, a new comprehensive study was established to investigate population change and impact during the outbreak under a wide range of forest conditions. Because the study area transects a large proportion of the original infestation as first mapped in 1972, the results are of special interest in evaluating the course of the outbreak. Therefore, this report deals primarily with the major findings from those specific population-impact studies. Many results are preliminary and subject to further analysis.

1/ Mason, R. R. 1974. Population change in an outbreak of the Douglas-fir tussock moth, *Orgyia pseudotsugata* (Lepidoptera: Lymantriidae), in central Arizona. Canadian Entomologist (in press).

2/ Mason, R. R., and C. G. Thompson. 1971. Collapse of an outbreak of the Douglas-fir tussock moth, *Hemerocampa pseudotsugata*, (Lepidoptera: Lymantriidae). USDA Forest Service Research Note PNW 139, 10 p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, Oreg.

3/ Wickman, B. E., R. R. Mason, and C. G. Thompson. 1973. Major outbreaks of the Douglas-fir tussock moth in Oregon and California. USDA Forest Service General Technical Report PNW-5, 18 p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, Oreg.

OBJECTIVES

Primary objectives of this study were:

1. To determine population change over a range of defoliation intensities in the third year (1973) of a tussock moth outbreak.

2. To evaluate the roles of the major causes of larval and pupal mortality and their interaction with host population density in the third year of the outbreak.

3. To determine the amount of tree mortality, top-kill, and growth loss in grand fir and Douglas-fir in relation to measured larval population and defoliation levels in 1973 and 1974.

4. To derive mathematical functions from field data to improve the prediction elements of population models.

METHODS AND STUDY DESIGN

The study was conducted using a split-plot design with six replications, four defoliation classes, and three time intervals. Natural tussock moth populations and resulting tree damage were investigated at six study sites (replications), covering about a 35-mile transect of the 1972 Blue Mountain infestation. Each replication included intensive sample plots in each of four defoliation classes (two replications had only three classes).

Evaluations of tussock moth population density, foliage weight loss, and natural mortality factors were made at 2- to 3-week intervals during the larval activity period in 1973 and 1974. Pupal and egg collections were also examined at each study site. All population and mortality data are being compiled and summarized in life tables.

To obtain supplementary information on defoliation, tree mortality, and top-kill, at least 10 or more 1/50-acre plots were established at each of the 22 population study areas. Individual case histories are being kept on all plot trees for at least 4 years.

In addition to field studies, supporting laboratory experiments were conducted to determine the effect of foliage quality on larval development and survival.

All field studies were protected from operational insecticide spraying and logging activities.

RESULTS

Population Change

High densities of early instar larvae were recorded at most study sites in June 1973. Plots with 1972 defoliation contained considerably higher densities than plots with no previous visible defoliation (Class IV). During

the summer of 1973 there was a sharp decline in numbers of larvae, followed by high pupal mortality. Rate of larval decline was significantly related to the degree of past defoliation. By June 1974, mean larval densities were low in each defoliation class and within the month had virtually collapsed on all study sites. Measured changes in density of small larvae from 1973 to 1974 are plotted in figure 1. Also shown (dashed lines) are probable trends of the population buildup in previous years as estimated from known defoliation and other monitor plots in the areas. Probable trends are based on the assumption of a 10-fold increase in larval population density in the release phase (1971-72). The trend lines in figure 1 clearly conform to the phases and patterns of a natural outbreak cycle of the tussock moth.

Natural Mortality of Tussock Moth Larvae

Measured causes of total population mortality for all plots are given in table 1. As in previous studies, the largest single mortality component for larvae is unknown. A high proportion of this unaccountable loss occurred early in the larval cycle and can probably be attributed to invertebrate predation, natural dispersal of small larvae, and, in the case of dense populations, starvation.

The mortality rates from both virus disease, and parasites tended to increase in the larval population through the summer and from 1973 to 1974. After the large loss of early instar larvae to unknown factors in 1973, virus disease accounted for a progressively larger proportion of mortality in the remaining populations. Virus also appeared to act in a compensating manner to other mortality factors. This was indicated by the relatively high rate (30 percent) of disease on previously undefoliated plots (Class IV) late in the season where mature larvae were still present in sufficient numbers because of good survival early in the season.

Virus disease is apparently predictable in larval populations from the level of disease incidence in eggs, as shown by a significant correlation between disease in fall-collected egg masses and field-sampled larvae the following year (fig. 2). Parasites accounted for less mortality among larvae than virus, but also may have been acting in a compensating manner. As shown in table 1, parasites had a heavy impact on 1973 pupae.

The laboratory experiments on effects of foliage quality may help explain some of the unaccountable losses of larvae and general population decline. In these studies a high population density situation was simulated by forcing larvae to feed on old-growth foliage. Larvae normally feed only on new foliage, if available, indicating that use of old growth is not a dietary requirement but the result of population density pressures. Feeding on old foliage results in increased frass production. This may be due to the fact that old foliage has less nutrient value which forces larvae to feed on larger volume of foliage or less of the old foliage is utilized by the larvae (fig. 3). Such feeding probably heralded a population decline by producing a subtle deterioration in population quality.

Feeding on old growth from the third instar to pupation also was found to prolong development time, increase frass production, reduce larval and pupal size, and decrease egg production and viability. Any factor affecting pupal weight had a direct effect on egg production (fig. 4).

Based on these results, mass starvation probably results in the field when early instar larvae are forced to feed on old foliage. The laboratory studies also pointed out different effects of host tree species. For example, populations can build up to outbreak levels on both Douglas-fir and grand fir but dense populations apparently survive better on Douglas-fir because young larvae adapt easier and feed more successfully on the old needles of Douglas-fir than on old foliage of grand fir. Subalpine fir, although fed upon, is not favored and probably does not contribute to a continuing outbreak.

Defoliation and Tree Mortality

The extremely high larval densities encountered in early summer of 1973 destroyed all of the new foliage on most of the plots in about 2 weeks. As described above, many larvae were not mature enough at this time to feed on older foliage, which resulted in a rapid population decline and much lighter feeding on older foliage of grand fir. Older foliage of Douglas-fir was more commonly destroyed in 1973. There has been consistently good new foliage recovery in 1974 on all plots.

A summary of tree mortality for 1972 and 1973 is shown in table 2. So far, Douglas-fir, which comprises about 15 percent of the stand on our plots, sustained a proportionally larger volume of tree mortality than grand fir. This was especially true in the lighter Defoliation Classes III and IV and relates to the more severe defoliation of Douglas-fir, compared with grand fir, in 1973.

Examination of plots for 1974 mortality is just being completed. Tree loss this year may be due to secondary bark beetles invasion of weakened trees (fir engraver and Douglas-fir beetle) and/or further tree decline caused by 1972, 1973, or/and defoliation. This type of mortality is continuing, but not at the rate experienced in some past outbreaks. No heavy concentrations of trees killed by bark beetles have been observed. However, 1974 tree killing by fir engravers will be determined in 1975, so mortality figures could be revised upward after next year's examinations.

Table 1.--*Proportional mortality by cause for larval and pupal populations on study plots*[1/] *in the Blue Mountain outbreak*

Mortality cause	1973		1974
	Larvae	Pupae	Larvae
	Percent		
Virus disease	7.2	9.3	26.9
Parasites	2.1	49.0	6.3
Unknown	88.2	17.2	62.6
Total	97.5	75.5	95.8

1/ 1973 data based on 22 study plots. 1974 data based on balance of 6 study plots where adequate populations survived for measurement.

Table 2.--*Tree mortality in board feet, expressed as percent of merchantable stand volume, caused by defoliation on study plots in the Blue Mountain outbreak*[1]

Host species	Defoliation class							
	I		II		III		IV	
	1972	1973	1972	1973	1972	1973	1972	1973
Grand fir	37.99	8.26	0.75	0.64	0	0.15	0	0
Total	*46*		*1*		*0.15*		*0*	
Douglas-fir	27.99	36.14	0	4.49	0	10.36	0	2.21
Total	*64*		*4*		*10*		*2.21*	

1/ Preliminary summary: fieldwork in progress as report being prepared.

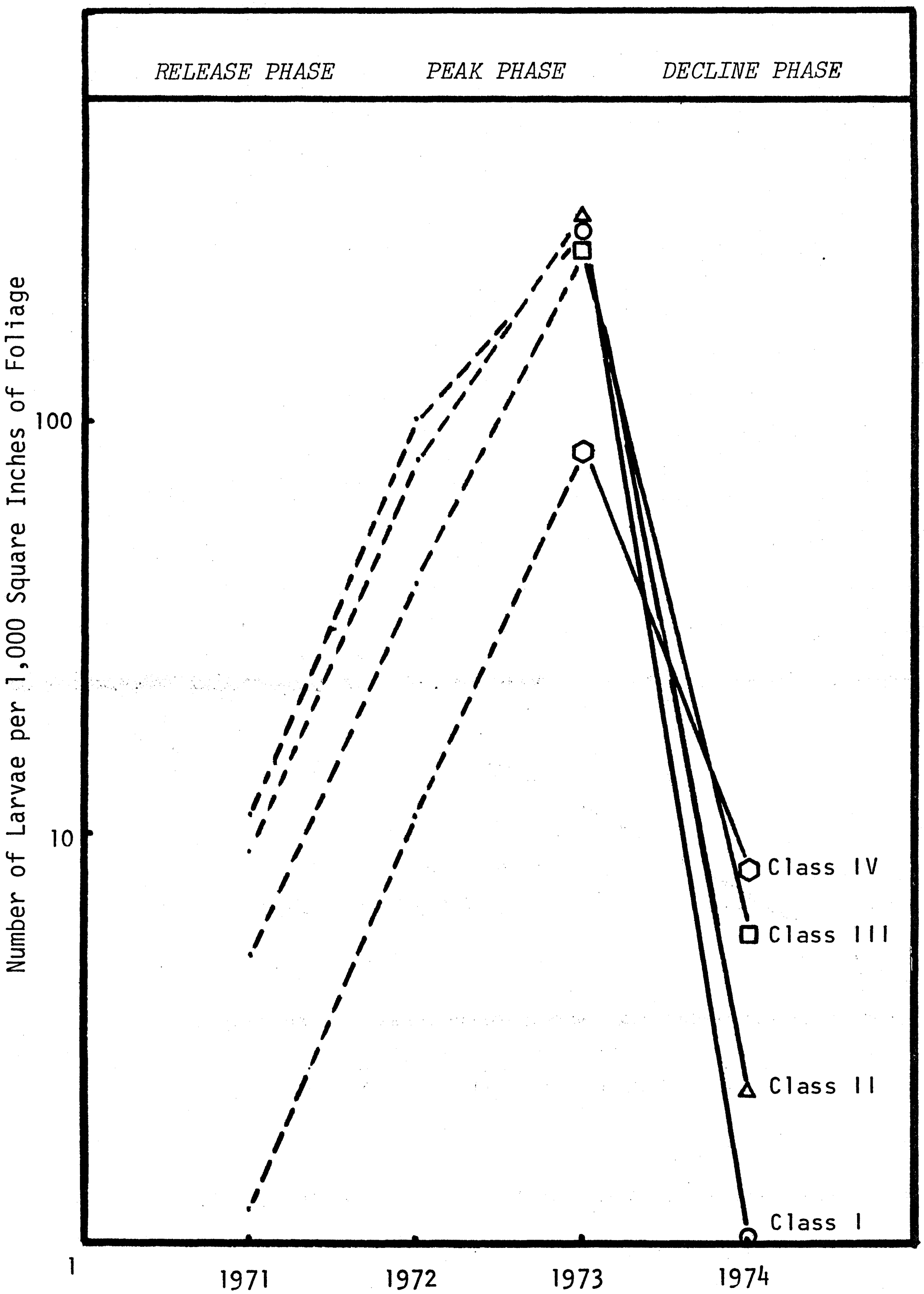


Fig. 1--Change in density of small tussock moth larvae on 22 study plots in the Blue Mountains outbreak. Dashed lines are assumed trends. Number of larvae are actually "number + 1" to accommodate a logarithmic transformation.

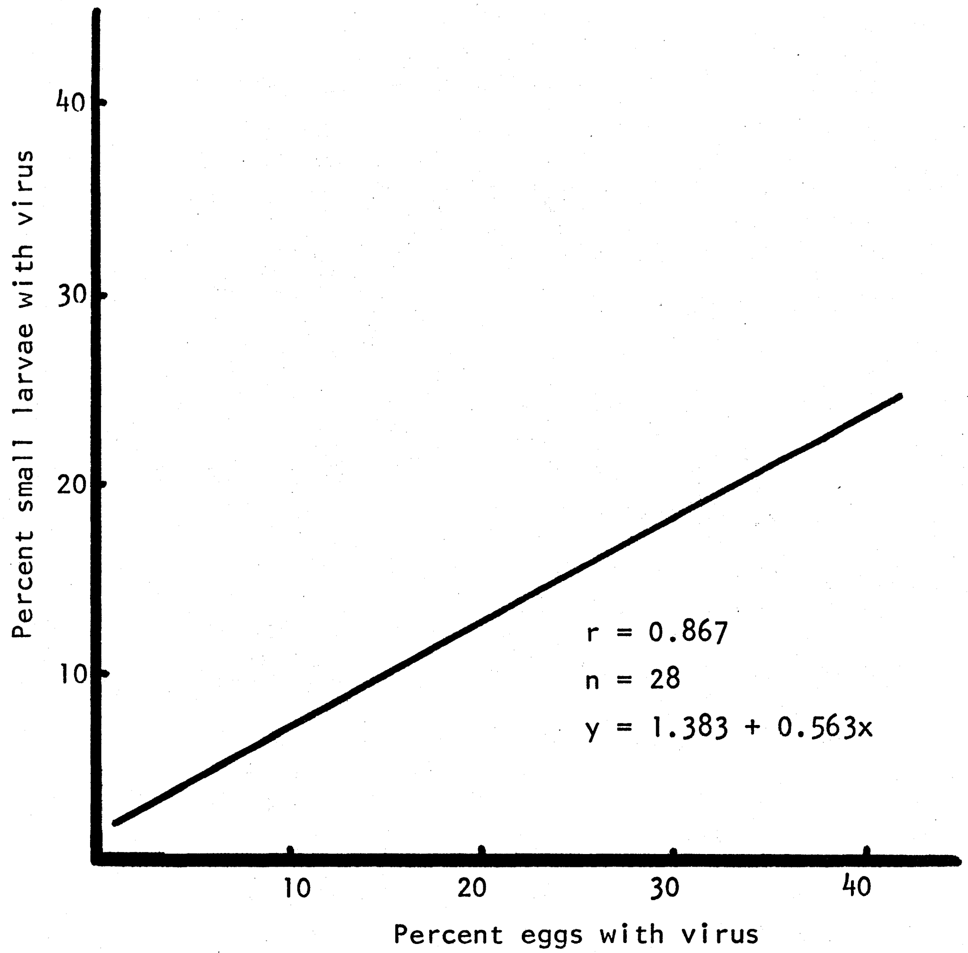


Fig. 2. Relationship between virus in fall collected eggs and in field sampled early instar larvae.

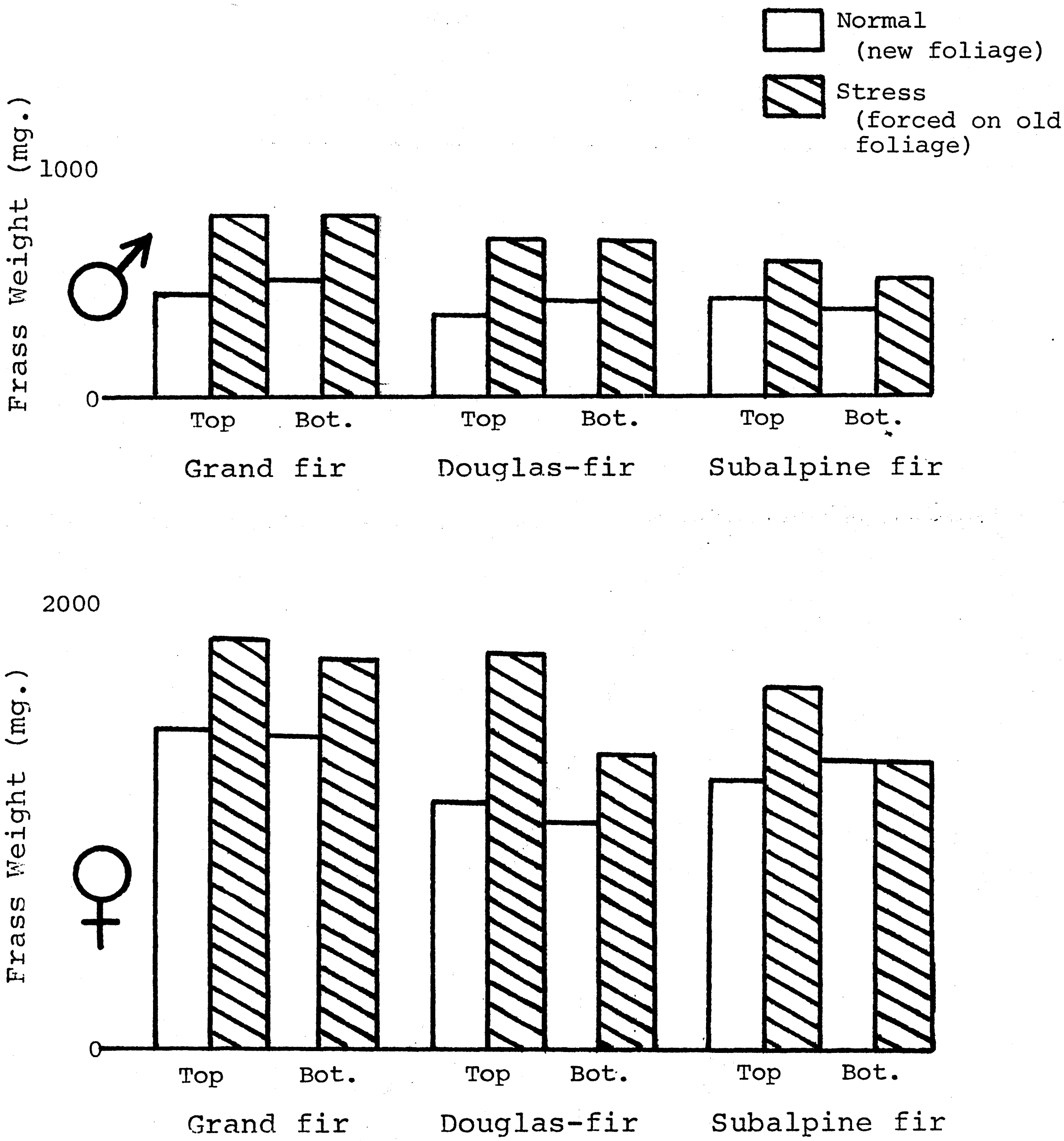


Fig. 3. Mean total frass production of Douglas-fir tussock moth larvae by sex and food class.

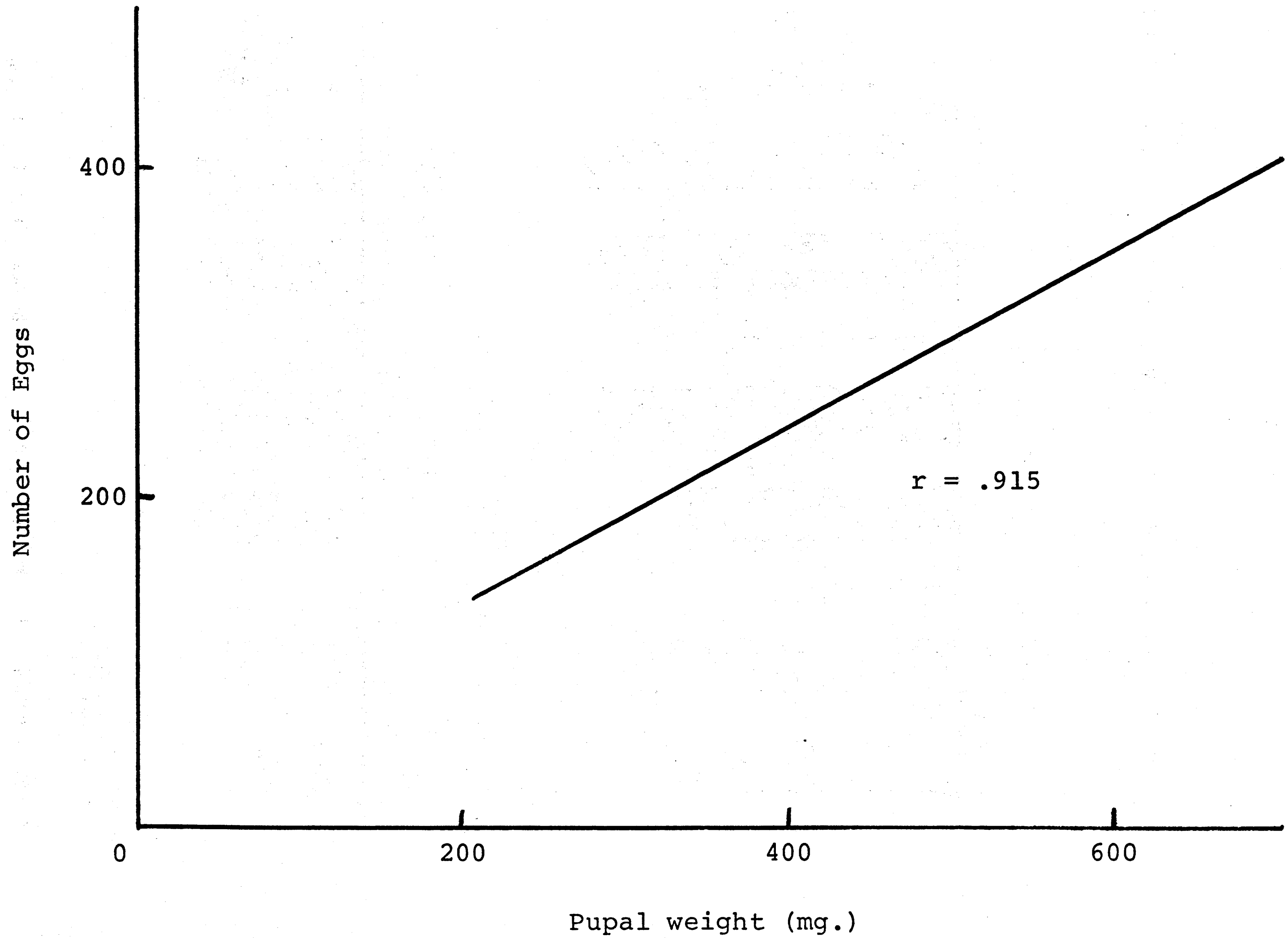


Fig. 4. Relationship of pupal weight and number of eggs for laboratory reared tussock moth.

Fig. 5.--Green weight (grams per inch of twig) of new grand fir foliage on 22 study plots in the Blue Mountain Outbreak.

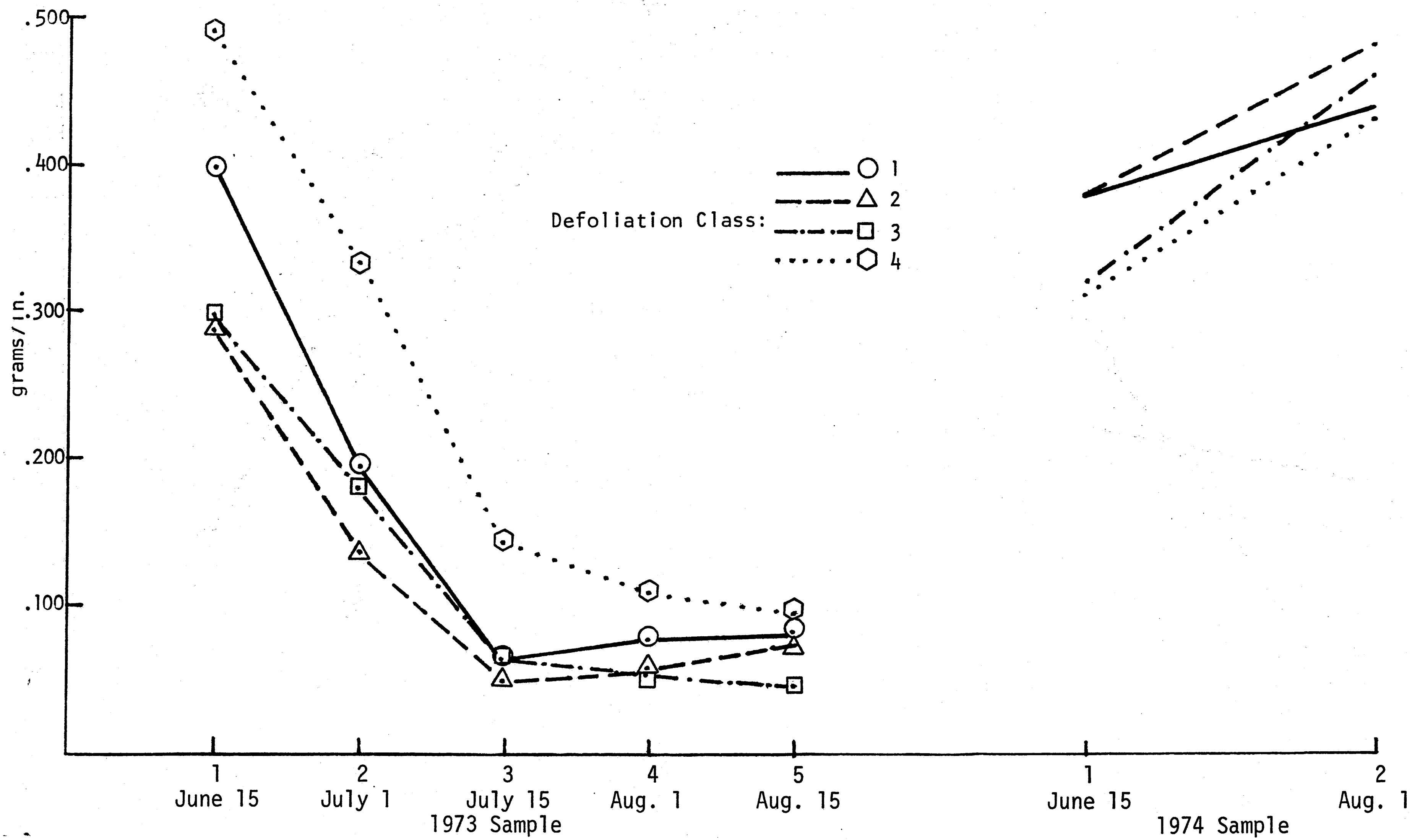
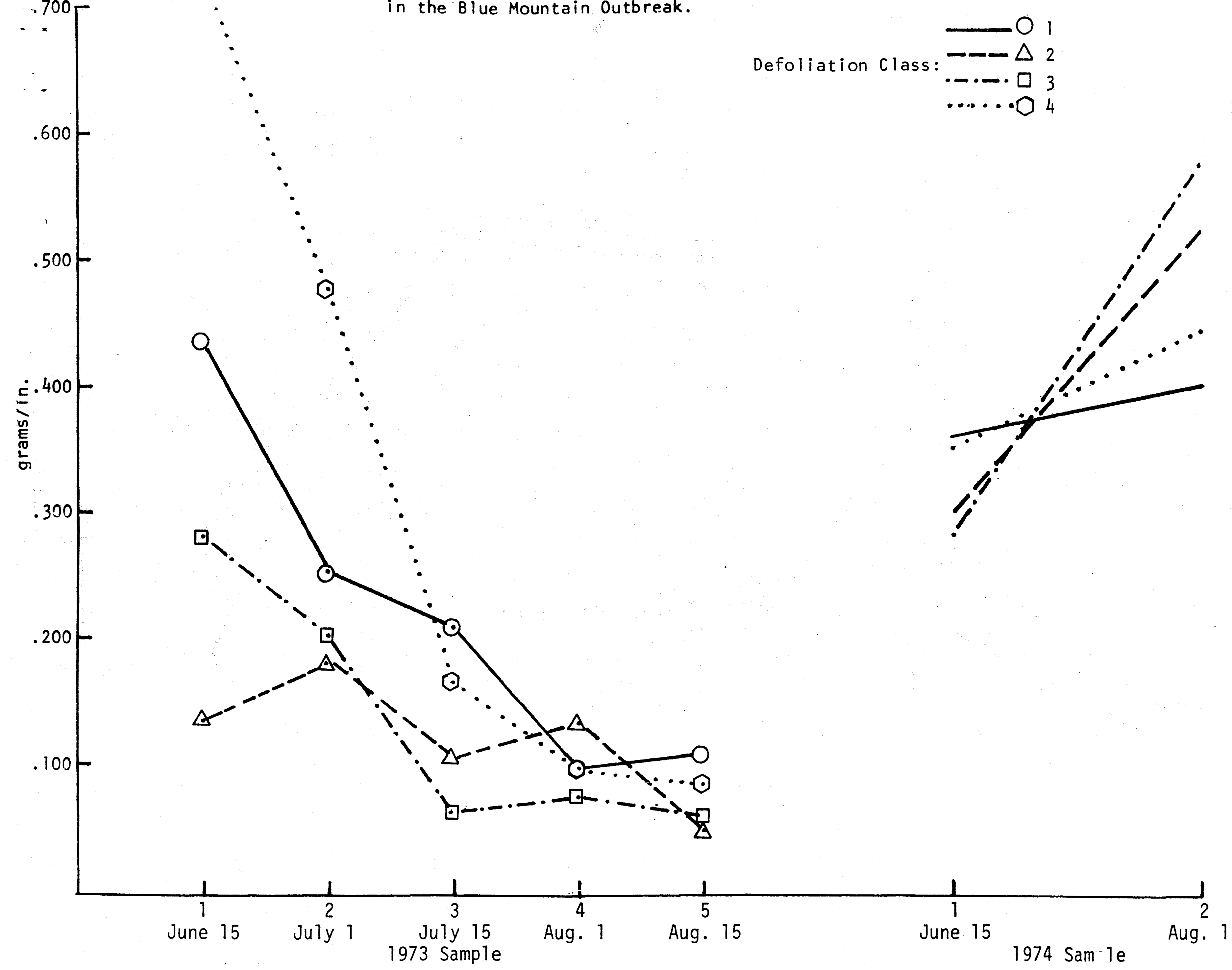


Fig. 6.--Green weight (grams per inch of twig) of new Douglas-fir foliage on 22 study plots in the Blue Mountain Outbreak.



STUDY NO. 2

AN EVALUATION OF AERIAL APPLICATIONS OF A NUCLEOPOLYHEDROSIS VIRUS AND *BACILLUS THURINGIENSIS* 1 YEAR AFTER APPLICATION

by

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In 1973, three formulations of nucleopolyhedrosis virus, two formulations of *Bacillus thuringiensis*, and one formulation combining the two insect pathogens were aerially field tested against the Douglas-fir tussock moth in northeastern Oregon. Population reductions exceeding 95 percent were obtained for all treatments except one formulation of *Bacillus thuringiensis*.[1/] The present report evaluates the effect of treatments in the year after application.

The tussock moth larval populations were measured on all plots on July 2, 1974, and again on August 13, 1974. The populations were in the second and third instar at the time of the first measurement and in the last (fifth and sixth) instars at the time of the second measurement.

Except in the untreated control plots and the plots treated with an unsatisfactory BioFilm formulation of *Bacillus thuringiensis*, the first population measurements, as shown in table 1, were all below 2 larvae per 1,000 square inches of foliage (the threshold of visible defoliation is 20 larvae per 1,000 square inches of foliage). The tussock moth populations in the untreated control and the *Bacillus thuringiensis*-BioFilm plots remained high through most of the 1974 season. By the time of the second sampling period, the tussock moth populations in the plots receiving the five effective formulations had dropped to negligible levels.

Tree mortality and visual estimates of defoliation were recorded in August of 1974. No tree mortality occurred in the treatments with virus (1X), virus (1X) + UV screen, virus (10X) + UV screen, combination of virus and *Bacillus thuringiensis*, or the molasses formulation of *Bacillus thuringiensis*. The 1974 flush of foliage was profuse throughout the entire crown of the trees on the plots in these treatments. The very

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1/ A manuscript reporting the results of these tests in the year of treatment has been submitted for publication. ("Aerial applications of nucleopolyhedrosis virus and *Bacillus thuringiensis* against the Douglas-fir tussock moth," by M.J. Stelzer, J. Neisess, and C.G. Thompson, submitted to Journal of Economic Entomology.)

low tussock moth larval populations caused no visible feeding damage in 1974.

In contrast, tree mortality was 49 percent on the untreated control plots and 1974 defoliation of the surviving trees averaged 50.4 percent. Tree mortality was 29 percent on plots treated with the BioFilm formulation of *B. thuringiensis* and defoliation of the surviving trees averaged 42.9 percent. Although many of the trees on the BioFilm plots produced a flush of 1974 foliage, this was destroyed by carryover tussock moth larval populations.

Table 1.--*Population density and mortality of Douglas-fir tussock moth larvae collected from the 1973 experiment plots at Enterprise, Oregon, on July 2, 1974*

Treatment (all at 2 gals. per acre)	Plot	Larval density[1/]	Number of larvae reared[2/]	Percent mortality		
				Virus	*B.t.*	Parasitism
1. Virus (1X) (100 billion polyhedra/acre)	C	0.6	3	33.3	0	0
	9	1.2	7	0	0	0
	1	.6	4	0	0	25.0
Average or total		.8	14	7.1	0	7.1
2. Virus (1X) + sunscreen	5	1.2	7	14.3	0	0
	11	.6	3	0	0	0
	F	1.1	6	33.3	0	0
Average or total		1.0	16	18.8	0	0
3. Virus (10X) + sunscreen (1 trillion polyhedra/ acre)	E	0	0	0	0	0
	2	0	0	0	0	0
	D	.8	5	40.0	0	0
Average or total		.3	5	40.0	0	0
4. *B.t.*-molasses	G	.8	5	20.0	0	20.0
	4	1.3	7	0	14.3	42.8
	1	1.6	7	28.6	0	14.3
Average or total		1.2	19	15.8	5.3	26.3
5. *B.t.*-BioFilm	3	14.3	84	13.1	2.4	14.3
	6	131.9	115	27.0	3.5	0
	5	73.6	54	20.4	0	1.8
Average or total		73.3	253	20.9	2.4	5.1
6. Combination of treatments 2 and 4	2	.5	3	0	0	0
	8	1.7	8	25.0	12.5	0
	H	1.2	6	16.7	0	0
Average or total		1.1	17	17.6	5.9	0
Control	B	22.7	90	17.8	1.1	2.2
	10	51.4	24	29.2	0	0
	12	6.6	9	22.2	0	22.2
Average or total		26.9	123	20.3	.8	3.2
All plots			447	20.1	2.0	5.1

1/ Larvae per 1,000 in^2 foliage, based on sampling 3 branches 18-20 inches long.

2/ Larvae originated from the density samples.

STUDY NO. 3

1974 FIELD EXPERIMENTS WITH *BACILLUS THURINGIENSIS* TO CONTROL DOUGLAS-FIR TUSSOCK MOTH IN IDAHO

by

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INTRODUCTION

Various formulations of the Douglas-fir tussock moth nucleopolyhedrosis virus (NPV) and Dipel, a commercial preparation of *Bacillus thuringiensis* (*B.t.*), were evaluated during 1973 field experiments conducted in eastern Oregon.[1/] The results showed that virus, at a dose of 100 billion polyhedra per acre applied at 2 gallons per acre in a 25 percent molasses formulation, and Dipel, at a dose of 7.26 billion International Units (1 pound per acre applied at 2 gallons per acre in a 25-percent molasses formulation), successfully controlled the tussock moth. Although these results were highly promising, followup experiments were designed for 1974 to further investigate application variables; they are reported here.

METHODS AND STUDY DESIGN

Low tussock moth population densities dictated a smaller experiment than originally designed. The objectives of the reduced experiment were:

(1) To compare efficacy of two new commercial liquid concentrates with the wettable powder *B.t.* product which was used in 1973;

(2) To obtain information on application of nonmolasses formulations, and

(3) To compare 1 gallon per acre application versus 2 gallons per acre rates.

The following treatments and control were included in the 1974 field experiment.

1/ Stelzer, M. J., J. Neisess, and C. G. Thompson. 1974. Aerial applications of a nucleopolyhedrosis virus and *Bacillus thuringiensis* against the Douglas-fir tussock moth. Manuscript submitted to Journal of Economic Entomology.

Treatment	Dosage (Billion I.U./acre)	Application volume (gallons)	Carrier
Thuricide 16B^R 2/	8	1	water
Dipel L.C.^R 2/ (Liquid concentrate)	8	1	water
Dipel^R W.P.3/ (Wettable powder)	7.3	2	25 percent molasses
Untreated control	--	--	--

The four treatments were replicated three times on 12, 20-acre study plots located in the Idaho Panhandle National Forest, east of Coeur d'Alene, Idaho. The treatments were assigned to the plots at random and applied June 27-30, when 80 percent of the larval population was in the second instar. The applications were made with a Bell 47G helicopter equipped with a 46-foot recirculating spray boom.

A 15-tree cluster was located in the center of each 20-acre study plot for deposit and tussock moth larval sampling. The population density measurements were made 1 or 2 days before treatment and at 2, 7, 21, and 35 days posttreatment. During each sampling period, larvae were collected for laboratory rearing to determine cause-specific mortality rates, i.e., *B.t.* and virus.

Spray deposit was sampled at the ground level, with aluminum plates and white cards, and from the foliage at midcrown level of each tree.

Defoliation estimates were made at the time of the prespray population sample in June and in September, after the conclusion of larval feeding. Visual estimates were made on each sample tree by dividing the foliated bole into six approximately equal length units and estimating the defoliation in each unit. Prespray defoliation estimates on each of the 12 plots selected for treatment showed the following:

2/ Thuricide is produced by Sandoz-Warner, Inc., and Dipel is produced by Abbott Laboratories.

3/ Hereafter referred to as the Dipel-molasses formulation.

No noticeable defoliation	Light defoliation; in upper crown only	Moderate to heavy defoliation all crown levels
Marie (Control)	Beauty (Control)	Plot 5 (Thuricide 16B)
Plot 30 (Dipel-molasses)	Elk (Control)	Plot 14 (Thuricide 16B)
	Plot 16 (Dipel L.C.)	Plot 15 (Thuricide 16B)
	Plot 22 (Dipel L.C.)	Plot 19 (Dipel-Molasses)
	Plot 31 (Dipel-Molasses)	Plot 20 (Dipel L.C.)

The treatments were assigned at random to the plots. None of the trees selected for tussock moth larval density sampling showed complete defoliation in any crown level during 1973, except for one tree on plot 14 and three trees on plot 15 that had the terminal 1- to 3-feet dead.

RESULTS

Final Defoliation Estimates

Visual estimates of defoliation in September, after the conclusion of larval feeding, showed that noticeable feeding in 1974 was confined to the top one-sixth portion of the foliated crown regardless of treatment. The plots were grouped by three defoliation classes (table 1). None of the *B. thuringiensis* treatments tested clearly demonstrated superior foliage protection qualities (or a lack thereof). However, two of the three plots treated with Dipel L.C. suffered over 30 percent defoliation. None of the plots treated with Thuricide 16B or the Dipel-molasses formulation suffered this level of defoliation, although initial population densities were generally greater than on the Dipel L.C. plots.

Cause-Specific Mortality

Results of the the rearing of larvae collected individually at the time of the population density sampling are summarized in table 2. Very low levels of natural virus infection were found in all of the pretreatment larval collections. The incidence of virus infection reached a maximum of 18.4 percent at 35 days in the control.

The incidence of infection of *B. thuringiensis* was significantly higher (.05 level) in treatments with Thuricide 16B and the Dipel-molasses formulation than with the Dipel L.C. treatment in the 7-day posttreatment collection.

Population Reductions

Prespray larval population densities were low compared with those in the 1973 field experiment conducted in Oregon (see footnote 1).

Population density and survival data are summarized in table 3. These data were subjected to analysis of covarience with the initial population densities used as the covariant (X) and the posttreatment population densities and survival ratios as the variables (Y). The adjusted treatment means, for a given sampling interval, were compared, using the Scheffé multiple comparison test (at $P < .05$).

All treatments showed significantly lower adjusted survival ratios than the untreated control at the 2-, 7-, and 21-day sampling intervals (table 3). No differences were found in survival ratios at the 35-day interval. Although no significant differences were detected between treatments for any sample interval, the 21-day survival data and the incidence of infection of *B. thuringiensis* at the 7-day interval (table 2) indicate that Thuricide 16B controlled the tussock moth better than did the Dipel L.C. or Dipel-molasses. Figure 1 shows the survival ratios plotted versus time. After rapid initial declines in population (0-10 days), the slopes of the treatment responses are approximately equal to that of the untreated control. This indicates that the microbial deposit was washed from the foliage, since in the 1973 experiment the slopes of the treatment responses were different from the untreated control for approximately 21 days.

Spray Deposit Assessment

Spray deposit sampled at ground level (plates and cards, table 4) was generally low. Recovery (based on gallon per acre values) ranged from 11 to 33 percent. The low drop densities indicate that only the larger spray droplets reached the ground level. Deposit values from the foliage (table 4) shows that equivalent amounts of *B.t.* reached the target with the 1 gallon per acre application rates of the Thuricide and Dipel L.C., as compared with the 2 gallons per acre rate of the Dipel-molasses. The 2 gallons per acre application rate provided better coverage in terms of volume and droplet density.

FORMULATION AND APPLICATION PROBLEMS

The Dipel L.C. formulation contained residues that clogged the filters and nozzles in the spray system. This caused a reduction in flow rate and application of less than the desired dosage. Effectiveness of all the treatments was probably reduced by two intense rainstorms that occurred 4 to 9 days after spraying.

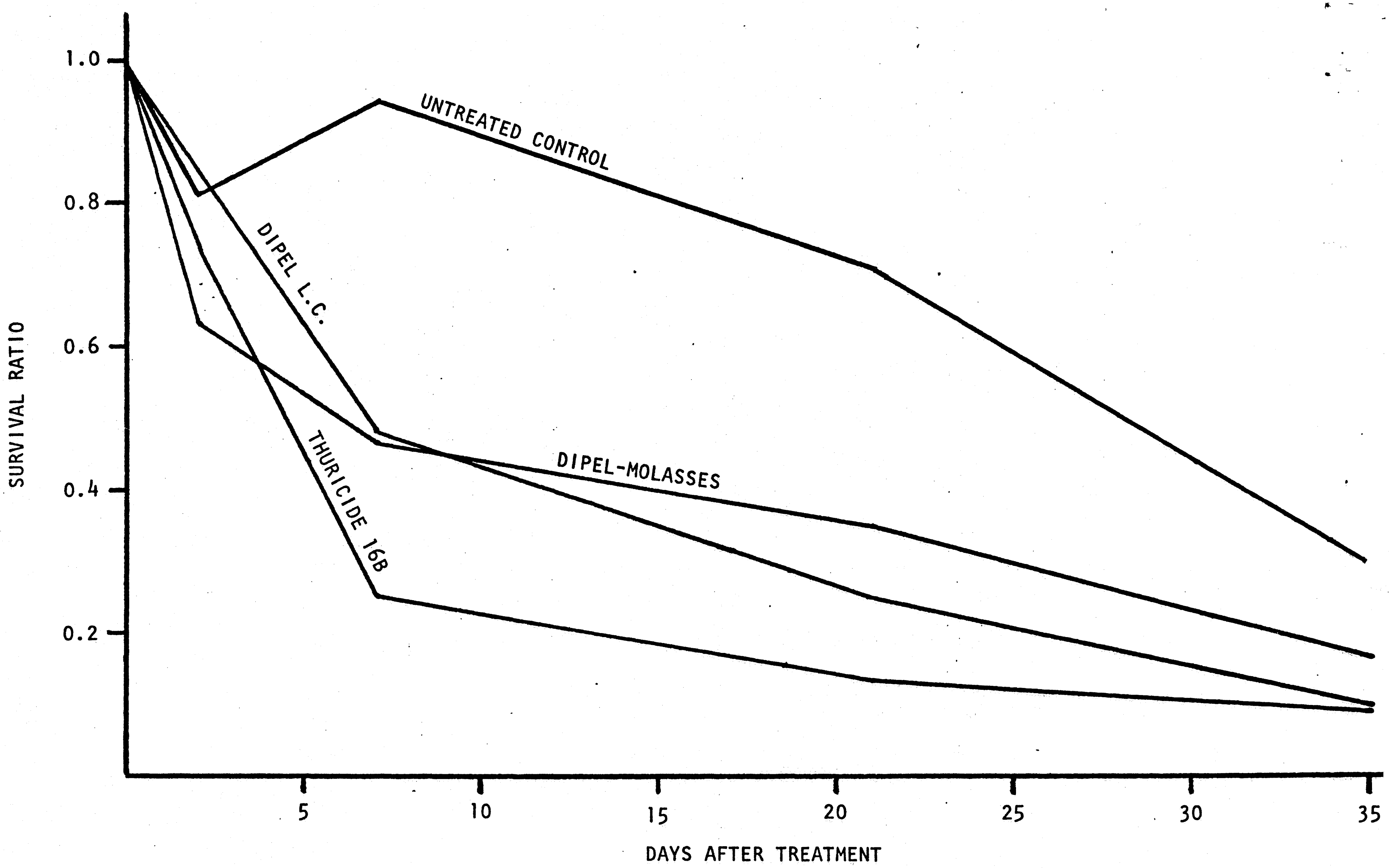

FIG. 1.--Survival ratios of tussock moth larvae for the various sampling intervals. Coeur d'Alene, Idaho, 1974.

Table 1.--*1974 defoliation on plots treated with* Bacillus thuringiensis

Defoliation class[1/]								
Less than 10 percent			10 to 25 percent			More than 30 percent		
Plot	Treatment	Population density[2/]	Plot	Treatment	Population density[2/]	Plot	Treatment	Population density[2/]
Beauty	Control	19.2	14	Thuricide 16B	79.6	Marie	Control	22.8
5	Thuricide 16B	57.1	15	Thuricide 16B	70.3	20	Dipel L.C.	79.2
16	Dipel L.C.	22.5	19	Dipel-molasses	50.2	22	Dipel L.C.	25.5
30	Dipel-molasses	23.5	31	Dipel-molasses	44.8			
			Elk	Control	42.6			

1/ Percent defoliation in the upper one-sixth of the foliated portion of the tree.

2/ Number of larvae per 1,000 square inches at the prespray sample.

Table 2.--*Cause specific mortality rates of* Orgyia pseudotsugata *(McDunnough) larvae collected before treatment and at 2, 7, 21, and 35 days after treatment. Larvae reared on artificial diet in laboratory after collection. Coeur d'Alene, Idaho, 1974*

Sampling interval	Mortality factor	Percent mortality by treatment:			
		Thuricide 16B	Dipel L.C.	Dipel-molasses	Control
Pretreatment	Virus	0.4	1.0	0.5	1.6
2-day	Virus	2.8	0	0	1.8
	B.t.	38.5	6.0	34.1	
7-day	Virus	1.5	2.9	0.8	4.0
	B.t.	42.1	12.3	31.8	
21-day	Virus	1.4	2.3	1.7	4.5
	B.t.	4.8	3.5	7.2	
	Virus + *B.t.*	0	0	1.3	
35-day	Virus	5.6	2.2	7.4	18.4
	B.t.	4.0	2.2	1.3	
	Virus + *B.t.*	0	0	1.3	

Table 3.--*Douglas-fir tussock moth larval density and survival. 1974 microbial field experiment at Coeur d'Alene, Idaho*

Treatment and plot	Larvae per 1,000 in^2 foliage					Survival ratio			
	Prespray	2-day	7-day	21-day	35-day	2-day	7-day	21-day	35-day
Control:									
Elk	42.6	41.8	44.7	36.3	17.6	0.981	1.049	0.852	0.413
Marie	22.8	14.6	23.0	12.0	4.1	.640	1.009	.526	.180
Beauty	19.2	13.0	11.0	12.0	3.9	.677	.573	.625	.203
Average	28.2	23.1	26.2	20.1	8.5	.766	.877	.668	.265
Thuricide 16B:									
5	57.1	34.5	15.7	5.5	4.6	.604	.275	.096	.080
14	79.6	66.8	19.1	9.0	4.9	.839	.240	.113	.062
15	70.3	51.5	21.9	12.3	10.1	.732	.312	.175	.144
Average	69.0	50.9	18.9	8.9	6.5	.725	.276	.128	.095
Dipel L.C.:									
22	25.5	9.4	14.4	7.8	3.9	.369	.565	.306	.153
16	22.5	13.0	4.0	5.6	2.6	.578	.178	.249	.116
20	79.2	82.7	43.1	20.2	7.4	1.044	.544	.255	.093
Average	42.4	35.0	20.5	11.2	4.6	.664	.429	.270	.121
Dipel-molasses:									
19	50.2	36.8	23.2	18.7	8.3	.733	.462	.372	.165
30	23.5	7.4	6.2	5.4	3.5	.315	.264	.230	.149
31	44.8	30.6	27.0	18.2	10.5	.683	.603	.406	.234
Average	39.5	24.9	18.8	14.1	7.4	.577	.443	.336	.183

Table 4.--*Deposit data from 1974 microbial field experiment at Coeur d'Alene, Idaho*

Treatment and plot	VMD (μ)	Deposit on:		
		Foliage (I.U./g foliage)	Plates (gal/acre)	Cards (drops/cm^2)
Thuricide 16B:				
5	269	2,446.85	0.296	15.1
14	303	1,663.92	.330	5.2
15	249	1,190.31	.322	10.3
Dipel L.C.:				
22	289	1,345.39	.112	2.9
16	284	1,425.70	.242	5.3
20	272	1,010.16	.213	5.9
Dipel-WP in 25 percent molasses:				
19	292	1,085.20	.396	12.0
30	329	928.24	.238	2.0
31	306	1,807.97	.540	19.1

STUDY NO. 4

PILOT CONTROL PROJECT OF NUCLEOPOLYHEDROSIS VIRUS AND *BACILLUS THURINGIENSIS* TO CONTROL DOUGLAS-FIR TUSSOCK MOTH POPULATIONS IN IDAHO - 1974

by

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INTRODUCTION

A pilot control project designed to evaluate two microbial insecticides, the bacterium *Bacillus thuringiensis* (*B.t.*) and a nucleopolyhedrosis virus, against epidemic populations of Douglas-fir tussock moth was planned for two test sites in northern Idaho in 1974. The outbreak in Idaho was believed to fit criteria for a definitive pilot project with virus and bacteria. These criteria[1/] were:

1. Relatively high Douglas-fir tussock moth larval densities.

2. A population in the release phase of the outbreak cycle.[2/]

3. A population with a low level of natural virus associated with the overwintering eggs.

The project was aborted shortly before spray application, due to a natural decline of tussock moth population and/or tussock moth populations not reaching expected levels. Because the project was so far along before being terminated, problems encountered in formulation of the microbial insecticides, insect population data, potential for tree damage in 1974, and other items are discussed--as reference material for future studies.

1/ Criteria described by M. J. Stelzer and J. Neisess. 1973. Study plan aerial applications of a nucleopolyhedrosis virus and *Bacillus thuringiensis* against the Douglas-fir tussock moth: population survival rates, initial residual levels of infection, spray deposit-mortality relationships. Unpublished report. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

2/ Defined by B. E. Wickman, R. R. Mason, and C. G. Thompson. 1973. Major outbreaks of the Douglas-fir tussock moth in Oregon and California. General Technical report PNW-5. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

METHODS

Locations of Study Areas

This pilot control project was established at two locations--Coeur d'Alene Mountain, south of Coeur d'Alene, Idaho, on the Idaho Panhandle National Forest, and Selway, south of Lowell, Idaho, on the Nezperce National Forest. Both materials were to be applied at each location.

Treatments

Treatments to be applied to epidemic Douglas-fir tussock moth populations included the most promising of each of the *Bacillus thuringiensis* and nucleopolyhedrosis virus formulations tested in eastern Oregon in 1973. On a per-acre basis, dosages were as follows:

Bacillus thuringiensis	
Dipel wettable powder (Abbott Laboratories, North Chicago, Ill.)	1 lb
Cargills Insecticide Base (molasses)	0.5 gal
Brilliant Sulfur Yellow Dye	7.6 g
Water to make 2 gallons of spray	
Virus	
100 billion polyhedra-nucleopolyhedrosis virus	
Cargills Insecticide Base (molasses)	0.5 gal
NaOH buffer	26.4 g
Brilliant Sulfur Yellow Dye	7.6 g
Sun Screen	1.0 lb
Water to make 2 gallons of spray	

Sample Design

Criteria for plot selection were that plots would have good accessibility and somewhat natural boundaries, relatively high Douglas-fir tussock moth populations, and defoliation more or less uniform among the plots. The sampling portion of the plots would be located a sufficient distance from the next plot to minimize contamination by spray drift. Distances would vary with terrain and wind patterns.

Two study areas were each divided into nine blocks (three virus, three bacteria, and three controls). Blocks varied in size from 1,000 to 3,000 acres due to differences in natural boundaries. Treatments were assigned to blocks randomly. A total of approximately 20,000 acres were scheduled for treatment with *B.t.* and 7,000 acres were scheduled for treatment with virus.

The selected sample design was a cluster sample, taking two branches per tree, five trees per cluster, and 16 clusters per block for a total of 80 trees per block. Clusters were to be located throughout the spray area.

STUDY NO. 9

RESULTS OF A PILOT TEST USING DYLOX (TRICHLORFON) TO CONTROL LATE LARVAL STAGES OF THE DOUGLAS-FIR TUSSOCK MOTH

by

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INTRODUCTION

Because of low tussock moth populations on test plots treated with Dylox (trichlorfon) early in the season, a decision was made in early July of 1974 to expand the testing of this material to determine its effectiveness against late larval stages of the insect. Test site locations were limited, as most moth-infested areas with adequate larval populations had either been sprayed or were so close to areas sprayed with DDT that the possibility of plot contamination by drift existed.

On July 5, a larval population survey was made of unsprayed areas. On the basis of these findings a decision was reached on July 6 to conduct the tests in an area 2 miles west of the Sled Springs Work Center, north of Enterprise, Oregon. This area is located on a flat ridge between Sled Springs Creek on the north and McCubbin Creek to the south in sections 21, 22, 27, and 28 of Township 3 North, Range 44 East. This area is easily accessible by Forest Service Road Number N323. Untreated check plot locations were available in an area reserved for research a few miles to the north.

OBJECTIVES

The objective of the expanded Dylox test of 1974 was to determine if this insecticide was effective in substantially reducing the number of late instar tussock moth larvae when applied under operational procedures.

METHODS

Except for modifications noted below, the expanded Dylox test followed the procedures outlined in the "Work Plan for Pilot Test of Carbaryl, Dylox, and DDT for Control of Douglas-fir Tussock Moth Larvae--1974" used in the early season tests near Halfway, Oregon. The modifications were necessitated by the late date of the decision to conduct the test. Time was not available to determine the incidence of natural virus present in the egg population or to make a pre-egg hatch assessment of foliage damage. Due to the small size of the area available for testing, only two replications of treatments were possible.

Two 300-acre plots, separated by a 200-foot buffer strip, were established on a ridge. Plot boundaries were marked with fluorescent cloth placed in the tops of trees and white paper strips on the ground. Sixteen, five-tree sampling clusters were located in each spray plot. Branches were removed from the midcrown of each tree and examined for tussock moth larvae within a 72-hour period before spraying and at 4- and 21-day intervals after spraying. Cluster sample trees were rated before spraying and again after feeding was completed for the degree of defoliation. During October, after egg laying was completed, four full branches from the midcrown of each tree were examined for new egg masses.

Two check plots were established in a nonsprayed area located 4 miles northwest of the sprayed plots in an area reserved for research. No DDT had been applied within 2 miles of these check plots. Larval and egg sampling and defoliation ratings were made at the same intervals and intensity on the check plots as on the sprayed test plots.

A Hiller 12-E helicopter was calibrated to apply Dylox[R] 1.5 oil undiluted at the rate of 1 gallon per acre (1.5 pounds active ingredient per gallon per acre). Application was made flying approximately 30 feet above the tallest trees at 50 miles per hour. This resulted in an effective swath width of 84 feet.

Application information for the two treatment plots follows:

	Plot 1	Plot 2
Location	Sec. 21 & 28	Sec. 22 & 27
Date sprayed	July 12	July 13
Acres	300	300
Gallons applied	300	300
Trichlorfon a.i. per acre	1.5 lbs.	1.5 lbs.
Time spraying started	9:02 a.m.	5:08 a.m.
Time spraying completed	11:16 a.m.	6:45 a.m.
Temperature range	53° to 57° F	46° to 49° F
Humidity range	88 to 63 percent	87 to 75 percent
Wind direction	West	None
Wind velocity	0-4.5 mph	None

Plugged spray nozzles caused a major delay during the application of the first load on plot 1. The plugging was partially remedied by removing and cleaning all filters and nozzles. The plugging, caused by sand in the formulated insecticide, caused only minor problems during the rest of the spraying.

Spraying of plot 1 was completed well within all the spray application guidelines, although spraying had to be delayed until 9:02 a.m. waiting for the foliage to dry completely because of rain the previous evening. Plot 2 was sprayed the following day under ideal spraying conditions.

Each morning before spraying, a red oil-sensitive spray deposit card was placed near each tree in the clusters to be sprayed. Immediately after

spraying, the cards were collected and sent to the Aerial Applications research unit at Corvallis for determination of spray coverage.

RESULTS

Prespray larval counts carried out 1 day before application of the Dylox showed a high population of fourth- and fifth- instar larvae present on both the treated and untreated plots. The counts, based on the number of live larvae per 1,000 square inches of foliage, ranged from 53 to 85 on the four plots. Counts made 4 days after application showed live larval populations of 15 and 8 per 1,000 square inches on the treated plots. Larval counts on check plots remained high at 64 and 42, respectively. The larval populations observed 1 day before spray, 4 days after spray, and the percentage of population reduction during this period are shown in table 1.

During visual observations made on the plots during the 2 weeks following spraying, many larvae were observed actively feeding. Some time between July 27 and August 3, when the 21-day postspray counts started, the moth population collapsed due to the natural virus disease. During the 21-day postspray examinations, many virus-killed larvae were observed on both the sprayed and check plots. Very few live larvae were found during this sampling period on any of the plots. The number of live larvae counted on each of the two sprayed plots was 1 larva per 1,000 square inches of foliage. The counts on the two check plots were 1 and 3 larvae per 1,000 square inches of foliage.

Since the tussock moth population had collapsed before making the 21-day postspray evaluation count, no analysis was made to determine the effectiveness of Dylox as of that postspray interval.

During October 1974, an egg mass survey was made on the test and check plots as outlined in the sampling plan. During this survey, no new egg masses were found on either the sprayed or untreated check plots.

The spray deposit coverage on the test plots is shown on table 2.

Very little defoliation was prevented by the treatments, as shown in figure 1.

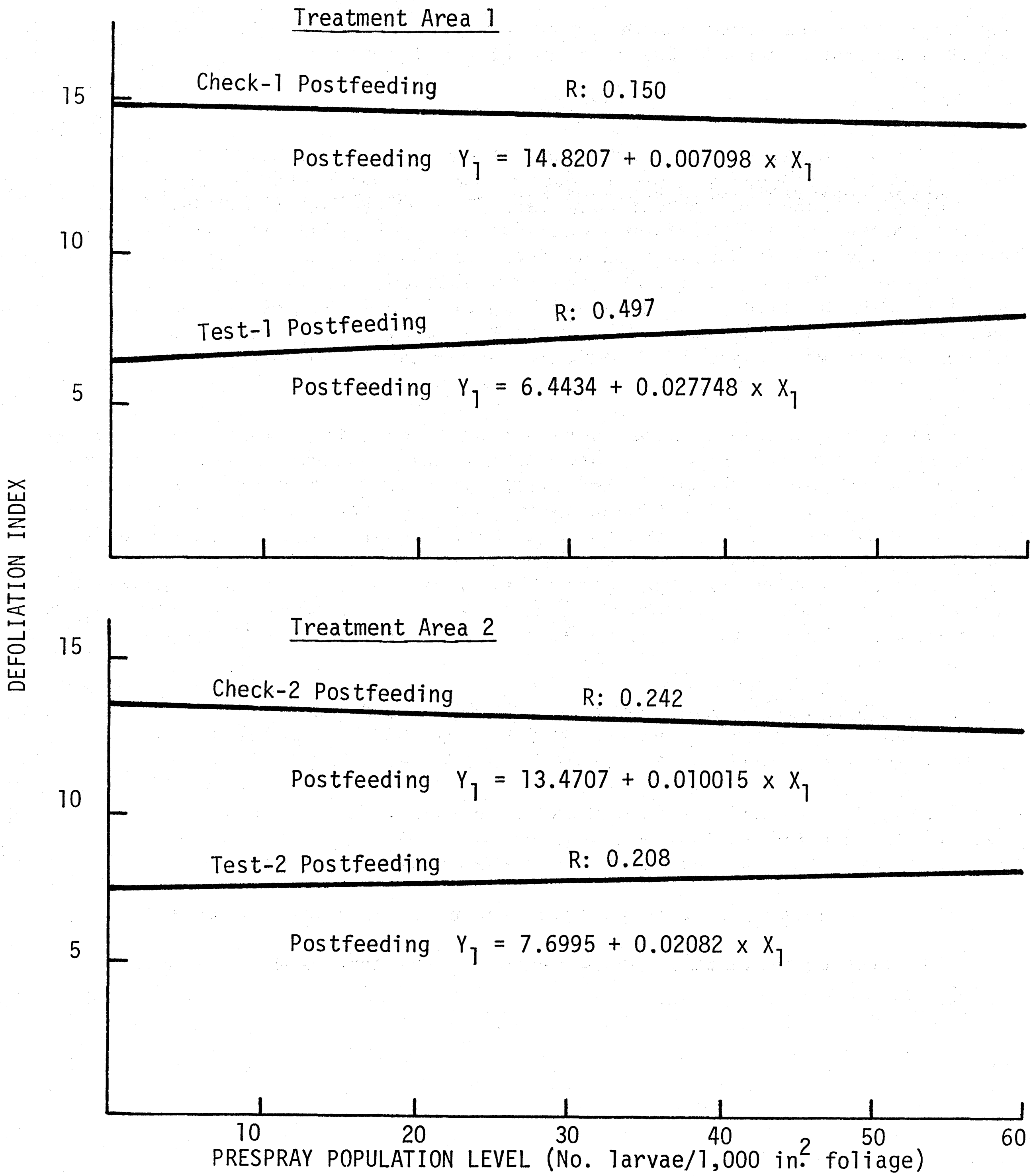

Figure 1.--Regression analysis showing differences in defoliation intensity as a result of treatment with Dylox.

Table 2.--*Spray deposit data from study on the expanded Dylox test for control of the Douglas-fir tussock moth*

Plot number	Dosage (lb/acre)	Coverage (gal/acre)
1	1.5	0.477
2	1.5	.577

Table 1.--*Prespray and 4-day postspray tussock moth populations on Dylox test and check plots, Sled Springs, 1974*

Plot	Insecticide	Prespray1/	4-day postspray1/	Percent reduction2/
Test 1	Dylox 1.5	60	15	68.4
Test 2	Dylox 1.5	53	8	78.6
Check 1	None	85	64	--
Check 2	None	57	42	--

1/ Number of larvae per 1,000 square inches of foliage.

2/ Percent population reduction using Abbott's formula which allows for natural mortality figures from check plots.

STUDY NO. 10

EFFECTIVENESS OF REDUCED DOSAGES OF DDT FOR CONTROL OF THE DOUGLAS-FIR TUSSOCK MOTH

by

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INTRODUCTION

In granting permission for the use of DDT against the Douglas-fir tussock moth in the spring of 1974, the Environmental Protection Agency stipulated that the U.S. Forest Service conduct additional tests to determine if reduced dosages of DDT (less than the standard 3/4 pound per acre) would effectively control this pest. Accordingly, as part of the 1974 DDT tussock moth control program, the U.S. Forest Service designated a 12,000-acre area for test purposes and treated parts of the area with DDT at the rates of 1/4, 1/2, and 3/4 pound of DDT per gallon of fuel oil per acre.

METHODS AND STUDY DESIGN

The study area was subdivided into 12 treatment plots. Treatments assigned to plots was determined by random selection with three plots each being used for the three dosages of DDT and three being set aside as untreated checks. Later, it was decided that the three check plots in the research area contained too much valuable timber and had too high a recreational usage to justify leaving them untreated. Accordingly, three alternate plots being used as part of a pilot control test located 5 miles to the east of the research area were used for the check plots. Within each plot 18 clusters of five trees each were selected for population counts. Insect populations were determined by removing two branches approximately 18 inches long from each tree, counting the number of larvae present, and converting this to a standard of larvae per 1,000 square inches of foliage. Sampling times in the DDT plots were: prespray, 7-day, 14-day, and 21-day postspray. In the check plots the same sampling design was used although sampling intervals were: prespray, 4-day, and 21-day postspray.

To assess sprayed deposit coverage, a 4x5-inch, white, treated card on a wire holder was placed beside each sample tree before spraying and collected within 2 hours after spraying. To make the spray solution visible, a red dye was added before loading into the helicopter. An electronic scanning device was used to read each card to determine drop density and average drop size. The volume of spray reaching the ground (gallons per acre) was determined by comparing the density of spots on these cards with standard cards containing a known amount of spray routinely used for this purpose.

Treatment of all the DDT plots was done as part of the operational tussock moth control program, using the same personnel, contractors, and equipment--a Loma helicopter with underslung bucket system and flying at 70 miles per hour. The same premixed DDT spray solution being used in the operational program was used but with the addition of the dye and enough clean diesel fuel to produce the desired rate of dilution.

RESULTS

Table 1 shows the results of analyzing the spray deposit assessment for the various treatments. Table 2 shows effectiveness of the various treatments. Population in the research plots was lower than had been expected. Also the population was in the declining phase, so that by the end of the season even in the untreated areas populations had decreased to low levels. Therefore, the results obtained in this experiment are only representative of a population in the declining phase of an outbreak.

The nine plots were not all treated at the same time. Each plot was treated when a certain percent of the egg masses had hatched. Treatment started on June 18 and ended on July 5. In general, the treatment was very good. The pilot knew that he was over an experimental plot and worked at achieving a uniform and accurate coverage.

The average droplet size reaching the ground was 287 microns (VMD). In general, the coverage at ground surface (gallons per acre) was higher than in similar earlier programs, but this may have been due to the use of a different method of determining coverage.

The application rate of 3/4 pound per acre of DDT was highly effective. No live insects were found on the 240 sample trees on three plots 7 days after treatment. In the three plots treated with 1/2 pound of DDT, 2 of the 240 trees had a few larvae on them 7 days after the treatment, but no larvae could be found at 21 days. In the plots treated with 1/4 pound of DDT mortality was excellent, although lower than in the 1/2 and 3/4 pound per acre plots. At 7 days mortality was 95 percent but had increased to 99 percent by 21 days, with live insects being found in 10 of the 240 trees. Spray deposit cards placed by each tree showed that the clusters in which survival had occurred had either been skipped or received very low treatment. The overall deposit in these clusters was less than 1/10 of a gallon per acre. Since 1/4 of a pound of DDT was being applied per gallon and these plots received less than 1/10 of a gallon per acre, the average amount of insecticide which reached the plots with surviving insects was less than 0.025 pound (0.4 ounce) per acre.

Table 1.--*Spray deposit data from study on reduced dosages of DDT for control of the Douglas-fir tussock moth*

Plot number	Dosage (lb/acre)	Drop size (VMD) (μ)	Drop density (No./cm^2)	Coverage (gal/acre)
1	3/4	293	4.63	0.714
2	3/4	283	4.62	.711
6	3/4	277	13.23	.503
3	1/2	277	5.83	.653
4	1/2	220	9.16	.555
8	1/2	317	11.01	.966
5	1/4	309	5.38	.584
7	1/4	301	4.16	.471
9	1/4	309	9.12	.596
Jolly	check	--	--	--
Corral	check	--	--	--
Big Elk	check	--	--	--

Table 2.--*Effectiveness of reduced dosage of DDT for control of the Douglas-fir tussock moth*

Plot number	Dosage (lb/acre)	Plot size (acres)	Number of larvae per 1,000 in^2 of foliage at:				Percent control at 21 days[1/]
			Prespray	7-day postspray	14-day postspray	21-day postspray	
1	3/4	555	6.7	0	0	0	100
2	3/4	1,175	4.2	0	0	0	100
6	3/4	1,324	5.9	0	0	0	100
			Average 21-day control				100[1/]
3	1/2	550	9.5	0.1	0	0	100
4	1/2	585	.5	0	0	0	100
8	1/2	1,125	13.2	0	0	0	100
			Average 21-day control				100[1/]
5	1/4	736	14.4	0.3	0.1	0	100
7	1/4	855	31.6	2.0	2.1	.9	97.2
9	1/4	1,200	16.4	.7	.6	1.0	99.4
			Average 21-day control				98.9[1/]
Jolly	check	500+	9.4	7.8[2/]	--	2.8	64.1
Corral	check	500+	11.0	7.8[2/]	--	5.1	53.6
Big Elk	check	500+	4.4	3.7[2/]	--	1.2	72.7
			Average natural decline at 21 days				63.5

1/ Not corrected for natural mortality.

2/ Reading made at 4 days rather than 7 days.

STUDY NO. 11

SMALL SCALE GROUND TESTS

TO EVALUATE CANDIDATE INSECTICIDES AGAINST THE DOUGLAS-FIR TUSSOCK MOTH

by

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INTRODUCTION

The U.S. Forest Service's screening program, conducted at the Pacific Southwest Experiment Station in Berkeley, California, has shown that many materials are potentially capable of controlling the Douglas-fir tussock moth.[1/] As a sequential step in this chemical evaluation program, the more promising insecticides were taken into the field in 1974 where they could be further tested against natural populations of the tussock moth under actual field conditions. These tests consisted of treating individual trees, using ground equipment calibrated to deliver spray at a rate comparable to that used in aerial application and in a similar droplet size range. Each day applications were made, three additional two-tree clusters were selected at random and left untreated to serve as checks.

METHODS

The study was conducted in an 11,000-acre block set aside by the Forest Service to be used for tussock moth research. The basic treatment unit was a two-tree cluster, using open-grown trees less than 15 feet high. Each treatment was applied at three different concentrations and the entire study replicated twice, with the first treatments applied to first- and second-instar larvae and the second treatment 3 weeks later to third and fourth instars.

Carrier solutions were either water or diesel fuel. The exception was BEM, which was furnished by the manufacturer in premixed solutions

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[1/] Lyons, R. L., H. W. Flake, Jr., and L. Ball. 1970. Laboratory tests of 55 insecticides on Douglas-fir tussock moth larvae. Journal of Economic Entomology. 65: 513-518.

of paraffin oil so that no further dilution was needed. Dosages were those recommended by the Forest Service laboratory in Berkeley, or by the chemical companies who supplied the materials.

Treatment was done from the ground using a backpack sprayer with a modified spinning-sleeve nozzle. The operator stood upwind of the pair of trees and directed the spray towards them so a spray cloud was formed and drifted into the tree. Three or more specially treated cards were hung around the periphery of each tree at the approximate level at which the insect population samples would be sampled. After treating for a predetermined number of seconds, the cards were examined and compared against a previously prepared series of standards. If the cards needed more spray to reach the level of the standard, the treatment was repeated until the desired amount of deposit showed on the spray card. The level of deposit aimed for was 0.1-0.5 gallons per acre, the amount which normally reaches the ground under forest conditions following an aerial application of 1 gallon per acre. Using the modified backpack sprayer, a droplet size of approximately 100 microns for oil and 250 microns VMD for water was obtained. This is slightly smaller than occurs in a normal aerial application.

The sample cards which had been placed out in the tree during treatment were analyzed in the laboratory to determine the actual amount of material which had landed on each of the trees. Insect population estimates were made by clipping three 18-inch branch samples from midcrown in the tree, counting the number of larvae on them, and converting this to the number of larvae per 1,000 square inches of foliage. Counts were made at 24 hours prespray and at 4, 7, and 10 days postspray.

The sampling design and operational procedures were developed by Environmental Research Associates Laboratories, Oswego, N.Y., a private research company contracted by the Forest Service to conduct the study. Besides the 14 experimental materials, three additional materials -- DDT, Sevin-4-oil, and Dylox -- were included as standards against which the experimental materials could be compared.

RESULTS

Table 1 shows the various insecticides chosen for the ground tests and the dosages at which they were applied, as well as their effectiveness. Table 2 shows the three materials used as standards and the untreated checks. The results varied considerably, but in general it appeared that most of the materials tested showed some potential for control of the tussock moth. At the dosage rate tested, the two materials which appeared most promising were Phosvel and FMC-33297. Both gave consistently high mortality when applied against both early and late instars. Orthene, Matacil, Imidan, Volatan, and Dursban gave more erratic results but appeared effective.

The growth-regulator materials tested did not appear as good in this test as they might have if the test had been designed more for their specific properties. Therefore, Zoecon's Altosid and Altozar would probably have appeared much better if application had been made against later instar larvae and percent control determined from the number of larvae which did not successfully pupate, since these two materials do not kill the larvae but interfere with pupation. Similarly, Thompson-Hayward's TH-6040 at 10 days gave only moderate control; however, whan an additional posttreatment count was made at 15 days, control of both early and late instar larvae increased to over 90 percent. Resmethrin appeared quite satisfactory against later instars but not against early instars.

In general, most of the chemical insecticides appeared to show some potential for tussock moth control. The exception was Bioethanomethrin which consistently gave low control. Another material which apparently gave poor control was Fundal; while controlling early instar larvae, it had very little effect on late instars. However, when Fundal was mixed with a *Bacillus thuringiensis* formulation, Dipel, some synergistic action may have been present, since mortality of late instars increased to above the acceptable level of 90 percent.

Table 1.--*Summary of 1974 ground testing of candidate insecticides against the Douglas-fir tussock moth*

Material and manufacturer	Dosages tested (lb/gal/acre)	Early instar larvae			Late instar larvae		
		Coverage (gal/acre)	No. larvae/1,000 in^2 before treatment	Percent control at 10 days	Coverage (gal/acre)	No. larvae/1,000 in^2 before treatment	Percent control at 10 days
Resmethrin	0.02	0.175	181.2	61.3	0.115	33.7	93.5
S.B. Penich & Co.	.04	.324	248.8	73.8	.024	31.4	100.0
	.1	.124	113.2	89.8	.056	64.2	99.2
Orthene	.25	1.55	67.9	99.6	.71	36.5	94.0
Chevron Chemical Co.	.5	.69	99.6	94.5	.44	33.6	92.0
	1.0	2.36	79.1	100.0	.92	36.0	100.0
Dursban	.125	.196	37.8	96.5	.031	161.3	92.9
Dow Chemical Co.	.25	.290	35.4	97.7	.036	132.0	100.0
	.5	.266	108.4	100.0	.113	80.0	96.5
TH-6040	.062	4.61	110.4	77.5	.216	27.6	83.7
Thompson-Hayward	.125	1.92	129.8	67.1	.31	47.4	93.5
Chemical Co.	.25	1.75	115.5	83.3	.16	24.1	93.4
Volatan (Phoxim)	.062	.192	64.7	95.5	.411	22.0	96.4
Chemagro Div.	.125	.175	81.4	99.0	.224	30.9	88.3
Baychem Corp.	.25	.092	55.8	98.6	.121	49.2	92.7
Fundal SP	.25	1.27	14.6	93.2	1.74	45.9	49.7
Nor-Am Agri. Products	.5	1.08	20.8	96.0	.68	50.2	72.1
Inc.	1.0	1.25	30.2	98.3	1.66	19.0	55.8
Fundal + Dipel							
Nor-Am Agr. Products	.125 Fundal + .125 Dipel	.49	111.5	88.6	0.70	23.3	92.1
Abbott Laboratories	.25 Fundal + .25 Dipel	1.18	65.6	97.0	0.71	28.0	97.5
	.5 Fundal + .5 Dipel	.77	116.8	99.1	0.98	34.3	100.0

Table 1.--*Summary of 1974 ground testing of candidate insecticides against the Douglas-fir tussock moth* (continued)

Material and manufacturer	Dosages tested (lb/gal/acre)	Early instar larvae			Late instar larvae		
		Coverage (gal/acre)	No. larvae/1,000 in^2 before treatment	Percent control at 10 days	Coverage (gal/acre)	No. larvae/1,000 in^2 before treatment	Percent control at 10 days
Phosvel	0.25	0.50	132.1	99.1	0.05	53.2	100.0
Velsicol Chemical Co.	.5	.35	135.2	99.3	.05	43.9	100.0
	1.0	.22	173.9	99.6	.09	48.5	100.0
Imidan	.25	2.32	54.3	89.3	--	20.2	91.6
Stauffer Chemical Co.	.5	1.48	43.3	100.0	--	38.4	96.1
	1.0	--	49.1	99.0	--	26.0	94.2
Altozar	.031	1.60	171.8	47.0	Due to a very poor showing on early instar treatment, not replicated on later instars.		
Zoecon Corp.	.063	2.77	53.4	43.1			
	.125	1.91	78.7	50.7			
Altosid	.032	.48	51.2	80.1	Due to a very poor showing on early instar treatment, not replicated on later instars.		
Zoecon Corp.	.063	.99	39.1	59.3			
	.125	1.40	60.4	42.8			
Matacil	.031	.28	72.6	94.9	.127	37.5	100.0
Chemagro Div.	.063	.51	72.3	93.1	.213	53.0	97.0
Baychem Corp.	.125	.27	60.3	95.9	.329	26.7	100.0
FMC-33297	.00312	--	--	--	--	18.3	98.4
FMC Corp.	.00625	--	--	--	--	15.7	87.0
Niagara, Chemical Div.	.0125	--	--	--	--	16.4	100.0
	.025	--	--	--	.47	58.3	100.0
	.05	1.07	48.2	100.0	.51	33.0	100.0
	.10	1.17	98.4	100.0	.60	24.5	100.0
	.25	.71	155.5	99.7	--	--	--

Table 1.--*Summary of 1974 ground testing of candidate insecticides against the Douglas-fir tussock moth* (continued)

Material and manufacturer	Dosages tested (lb/gal/acre)	Early instar larvae			Late instar larvae		
		Coverage (gal/acre)	No. larvae/1,000 in^2 before treatment	Percent control at 10 days	Coverage (gal/acre)	No. larvae/1,000 in^2 before treatment	Percent control at 10 days
Bioethanomethrin	BEM-2853 1/	(2/)	37.7	--	(2/)	27.0	82.2
McLaughlin Gormley	BEM-2854 1/	(2/)	37.2	65.3	(2/)	16.3	96.9
Kiney Co.	BEM-2854 1/	(2/)	80.4	71.4	(2/)	25.2	81.3
	BEM-2856 1/	(2/)	51.8	89.4	(2/)	32.2	89.9
	BEM-CR 1/	(2/)	66.8	82.6	(2/)	33.6	83.0

1/ Company provided formulated material ready for application. No information was provided on dosage.

2/ Carrier solution was unknown; therefore determination of coverage by analysis of spray deposit card was impossible.

Table 2.--*Summary of standards and checks used in 1974 ground tests against the Douglas-fir tussock moth*

Material and manufacturer	Dosages tested (lb/gal/acre)	Early instar larvae			Late instar larvae		
		Coverage (gal/acre)	No. larvae/1,000 in^2 before treatment	Percent control at 10 days	Coverage (gal/acre)	No. larvae/1,000 in^2 before treatment	Percent control at 10 days
DDT	0.25	0.422	65.5	100.0	0.011	30.0	99.0
	.50	.388	230.2	99.7	.015	29.0	96.2
	.75	.439	198.7	100.0	.02	13.7	100.0
Sevin-4-oil	.5	.248	192.8	99.6	.148	37.2	90.6
Union Carbide Corp.	1.0	.311	348.2	99.5	.100	25.4	90.6
Agricultural Prod.	2.0	.152	64.5	98.9	.163	24.9	100.0
Dylox	.5	(1/)	78.2	98.1	(1/)	37.1	88.7
Chemagro Division	1.0	(1/)	68.9	84.1	(1/)	61.7	96.9
Baychem Corp.	1.5	(1/)	59.6	77.2	(1/)	27.9	98.9
Untreated check				94.4			28.6
clusters				44.2			82.3
				84.3			48.9
				13.9			
				69.1			

1/ Due to problem in analyzing spray deposit cards, no coverage estimates could be made.

STUDY NO. 12

INSECTICIDE ORTHENE PERFORMANCE IN FIELD TRIALS FOR CONTROL OF THE DOUGLAS-FIR TUSSOCK MOTH

by

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and

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INTRODUCTION

The U.S. Forest Service in 1974 undertook a series of ground and aerial tests of candidate insecticides for control of Douglas-fir tussock moth in northeastern Oregon. Earlier tests had shown the insecticide Orthene to be very effective against a similar forest defoliator, the gypsy moth, in the northeastern United States.

In particular, the Forest Service was interested in the potential high selectivity of Orthene for certain forest defoliators. Orthene is a systemic insecticide. The amount remaining on the outside of the needles biodegrades within a matter of days, while the material in the needles remains active for several weeks. Therefore, surface insects, such as beneficial parasites and predators, walking on the needles a few days after treatment are not affected, but needle-feeding animals, such as caterpillars, are.

For these reasons, the Forest Service decided that further testing of Orthene was justified. A cooperative study was set up between the Forest Service and Chevron Chemical Co. to undertake small-scale aerial tests to determine the effectiveness of Orthene in controlling the Douglas-fir tussock moth. Application was at two different rates--1 pound per acre and 1/2 pound per acre--and was compared against the standard treatment of DDT (3/4 pound per acre).

METHODS AND STUDY DESIGN

The study was conducted in northeastern Oregon. The six Orthene plots and three control plots were part of an 11,000-acre block of land set aside by the Forest Service for tussock moth research. The three DDT plots were 4 miles west of the other plots, in an area that was being sprayed operationally with DDT for tussock moth control.

The field experiment was conducted by Chevron Chemical Co., the manufacturer of Orthene. Forest Service involvement in the program was

primarily in helping Chevron locate areas suitable for the test, preparing the study plan, advising on the insecticide application, population measurement, and in evaluating data. Plot location, layouts, selection of sample trees, application, and posttreatment sampling were all conducted by Chevron's personnel.

Each 20-acre treatment plot surrounded a 2- to 3-acre cluster of open-grown trees which were used for sampling. Nine plots were set up and randomly selected for treatment with 1 pound or 1/2 pound of Orthene or left untreated for checks. The three DDT plots were randomly located in an area to be operationally sprayed with DDT. The Orthene was applied in water at 2 gallons per acre from a Bell 206 Jet Ranger helicopter.

Insect populations were determined by removing three branches, approximately 18 inches long, from each tree at pretreatment and various posttreatment sampling periods. The insects on each branch were counted and the total number converted to an average number per 1,000 square inches of foliage. The branch samples removed at pretreatment and at 21-day posttreatment were brought into the laboratory where the amount of foliage consumed by the tussock moth was determined by examining each new terminal and counting the number of eaten and uneaten needles. To determine spray deposit coverage, a 4- by 5-inch, specially treated, white card on a wire holder was placed beside each of the sample trees just before treatment. A black, water-soluble dye was added to the Orthene spray solution so the spots would show up on this card; undyed DDT droplets were recovered on special, oil-sensitive cards. The cards were collected after treatment and brought into the laboratory where the spots were counted and measured to determine their average size and density and used to estimate the volume of material reaching the ground beside each tree.

RESULTS

The tussock moth larval population was suitable for the study; high egg hatch occurred, with little loss to predation during the first instar. It was known that virus was present in the larvae and would sooner or later show up and decimate the population. However, posttreatment counts at 2, 7, 14, and 21 days showed no virus. The 4-week posttreatment count found virus in over 10 percent of the insects examined in the check plots, and by 5 weeks the population had completely collapsed. For this reason, results of the study are shown only up to 21 days.

Spraying of all six Orthene plots was completed on the morning of June 23, and the DDT plots were treated the following day. The weather for both DDT and Orthene spraying was excellent. No problems were encountered in mixing or applying the Orthene solution.

The coverage data for the nine plots are in table 1. Orthene unexpectedly showed a very large drop size. Previous studies with water-based formulation had led us to expect a droplet size of approximately 300

VMD. What was obtained was closer to 500 microns. A possible cause of this difference may be an increase of viscosity due to the addition of the Orthene. In general, this is not desirable, since the larger the drop size, the fewer the drops produced and the poorer the penetration into the forest canopy.

A problem also occurred in treatment of plot 4. Although weather and other conditions appeared no different than for the other plots, plot 4 received on the average only about one-third as much Orthene--as determined on spray cards. Accordingly, this plot had the highest insect survival.

Data on the control of the insect population are shown in table 2. Orthene has a comparatively low initial contact toxicity and is most active only after the insect has eaten treated foliage. Accordingly, control at 2 days was comparatively light. Most mortality had not occurred until at least 7 days later, and the study suggests that some mortality was occurring as late as 2 weeks after treatment. The 1 pound of Orthene per acre was more effective, and the 97.6 percent mortality of the insects at 3 weeks was considered to be very acceptable control. The 1/2 pound of Orthene produced approximately 90 percent control at 3 weeks on two of the plots. However, plot 4, which is the plot which received the poorest coverage, showed only 76 percent control.

Larval density and percent population reduction data were analyzed by analysis of variance at the separate sampling intervals. Treatment means were compared by the Tukey's w-procedure at the 0.05 level (table 3). All chemical treatments reduced the tussock moth populations below the level of the check for each sampling interval. At 2 days, the reductions resulting from DDT applications were better than either of the Orthene applications. However, of the remaining sampling intervals, there was no difference between the level of control from the 1 pound Orthene versus DDT.

Spraying was done when the hatch was over 95 percent complete. At this time, the larvae had begun to feed and damage the new foliage. By 5 weeks posttreatment, when the final foliage examination was made, differences in the amount of foliage protection by the various treatments were quite evident (table 4).

Table 1.--*Spray deposit data for Orthene test against the Douglas-fir tussock moth*

Plot	Dosage (lb./acre)	Rate (gal/acre)	Average droplet size, (VMD) (μ)	Drop density (No/cm^2)	Actual coverage at forest floor (gal/acre)
Orthene					
2	1/2	2	461	16.20	0.86
4	1/2	2	507	5.40	.36
7	1/2	2	541	17.20	1.4
3	1	2	502	13.67	.91
5	1	2	509	15.86	1.1
6	1	2	589	10.73	1.2
DDT					
10	3/4	1	279	4.45	.5316
11	3/4	1	209	3.63	.1765
12	3/4	1	241	6.13	.4597

Table 2.--*Reduction of Douglas-fir tussock moth larval population following aerial application of Orthene*

Formulation	Plot number	Number of larvae per 1,000 in^2 foliage[1/]				
		Prespray	2-day postspray	7-day postspray	14-day postspray	21-day postspray
Check	1	112	54 (51.8)	44 (60.7)	81 (27.7)	71 (36.6)
	8	223	252 (13.0)	163 (26.9)	38 (82.9)	50 (77.6)
	9	113	66 (41.6)	63 (44.2)	65 (42.5)	52 (53.9)
Average natural decline at 21 days						61.4 percent
Orthene - 1/2 lb	2	109	47 (56.9)	15 (86.2)	15 (86.2)	10 (90.8)
	4	183	85 (53.6)	55 (69.9)	49 (73.2)	44 (75.96)
	7	274	93 (66.1)	32 (88.3)	12 (95.6)	26 (90.5)
Average control at 21 days						85.9[2/]
Orthene - 1 lb	3	148	44 (70.3)	13 (91.2)	8 (94.6)	5 (96.6)
	5	147	55 (62.6)	17 (88.4)	8 (94.6)	6 (95.9)
	6	240	47 (80.4)	11 (95.4)	2 (99.2)	2 (99.2)
Average control at 21 days						97.6[2/]
DDT - 3/4 lb	10	207	0.0 (100)	0.33 (99.8)	(3/)	0 (100)
	11	155	.33 (99.8)	0 (100)	(3/)	0 (100)
	12	226	.2 (99.9)	.4 (99.8)	(3/)	0 (100)
Average control at 21 days						100 percent[2/]

1/ Figures in parentheses are the percent control for each reading.

2/ Not corrected for natural mortality.

3/ No counts made at 14-day postspray on DDT plots.

Table 3.--*Mean percent larval mortality*

Treatment	Postspray counts (days)			
	2	7	14	21
Check	35.46a[1/]	43.93a	51.03a	56.03a
Orthene--1/2 lb	58.86b	81.26b	85.00b	85.75b
Orthene--1 lb	71.10c	91.66c	96.13b	97.23c
DDT--3/4 lb	99.90d[2/]	99.86c	--	100.00c

1/ Means in each column with the same letter are not different (P = .05).

2/ Test of significance involving DDT may be invalid because of lack of variation between the three replicates.

Table 4.--*Foliage protection determined by visually examining all new terminals on three branch samples per sampling tree*

Formulation	Plot number	Pretreatment		5-week posttreatment	
		Number of terminals examined	Percent of needles destroyed	Number of terminals examined	Percent of needles destroyed
Check	1	381	0.8	359	46.7
	8	240	7.2	341	91.4
	9	296	1.1	319	66.1
Average			3.0		67.7
Orthene--1/2 lb	2	303	.11	329	25.7
	4	502	.05	303	66.2
	7	266	9.6	370	72.8
Average			3.2		55.3
Orthene--1 lb	3	396	.2	135	31.6
	5	273	1.8	140	23.3
	6	204	13.9	170	65.9
Average			5.3		38.9
DDT--3/4 lb	10	(1/)	(1/)	135	36.6
	11	(1/)	(1/)	140	19.7
	12	(1/)	(1/)	170	21.5
Average			3.1 1/		25.5

1/ Average of 38 branches randomly selected from all three plots.

STUDY NO. 13

CHEMICAL IDENTIFICATION AND DEVELOPMENT OF THE TUSSOCK MOTH SEX PHEROMONE FOR IMPROVEMENT OF DETECTION METHODS

by

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INTRODUCTION

Tussock moth populations can increase so quickly that epidemics are often not detected until the forest has suffered severe damage. A study to identify this insect's sex pheromone was undertaken with the belief that availability of such an attractant would vastly improve detection capabilities, particularly for low-level populations. With the assistance of supplemental emergency funding for tussock moth research, a cooperative study on pheromone identification by the Forest Service and the Oregon Graduate Center, Beaverton, Oregon, was initiated in July 1973.

METHODS

Chemists at the Oregon Graduate Center pursued classic methods of analytical chemistry to isolate, purify, and identify the attractant chemical. Principal analytical techniques included dry-column chromatography, gas chromatography, mass spectrometry, and a combined gas chromatography-mass spectrometry system. Methylene chloride extracts of insect material containing the natural pheromone were prepared by Forest Service entomologists. The Forest Service also developed laboratory and field behavioral bioassay systems which were continually used for evaluation and support of the chemical identification effort.

RESULTS

The sex pheromone of the tussock moth was isolated and identified as (E)-6-heneicosen-11-one. This compound has been synthesized and field tested. Adhesive traps baited with microgram quantities of the synthetic chemical provide a more sensitive detection method than has been available in the past. Sex pheromone traps were successful in capturing male moths in many forest locations where the insect could not be detected by any other sampling method.

STUDY NO. 14

GROUND APPLICATIONS OF *BACILLUS THURINGIENSIS* AGAINST THE DOUGLAS-FIR TUSSOCK MOTH IN NEW MEXICO

by

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INTRODUCTION

Tussock moth outbreaks occur not only on forest lands but also on ornamental trees in urban situations. Therefore, in addition to the need for control in forests, there is also need for treating infestations on ornamentals in residential and high-use recreational areas where chemical pesticide use may be undesirable or prohibited.

The objective of this study was to test the effectiveness of *Bacillus thuringiensis* applied by hydraulic sprayer to control the Douglas-fir tussock moth in ornamental trees. There was confidence that control was possible because, in 1973, aerial application of Dipel^R (Abbott Laboratories, N. Chicago, Illinois), a commercial preparation of *Bacillus thuringiensis* at a dose of 7.26 billion international units (1 pound) in 2 gallons of molasses per acre successfully controlled the tussock moth in field tests conducted in eastern Oregon.

LOCATION OF STUDY

The test was conducted against an infestation of the Douglas-fir tussock moth in a mixed stand of Douglas-fir, white fir, and spruce in the courtyard of St. Vincent Hospital in Santa Fe, New Mexico. The courtyard covered an area of about 0.6 acre. A roadway that bisected the area was used as a buffer for dividing the infested trees into two groups of 10 trees each. One group was sprayed with *B. thuringiensis* and the other left untreated as the control.

FORMULATION AND APPLICATION

Composition of the microbial spray formulation, based on a total volume of 10 gallons of spray, was as follows:

1. Cargill Insecticide Base (Cargill Co., Minneapolis, Minn.), a spray adjuvant: 0.5 gallon.

2. Dipel^R WP, containing 7.26 billion international units of potency per pound: 0.2 pound.

3. Water: 9.5 gallons.

A commercial pest control operator applied the formulation using a hydraulic sprayer and a Bean spray gun (model number 4990) fitted with a D-8 orifice disc. The sprayer was operated at a tank pressure of 300 pounds per square inch. The trees were sprayed from 7:45 to 8:15 p.m. on May 29, 1974.

POPULATION DENSITY SAMPLING

Larval population density samples were taken about 8 hours before spraying, and at 2, 7, and 14 days after spraying. Sampling consisted of counting the number of larvae and measuring the foliage area on three 18- to 20-inch branches cut from the midcrown level of each tree. This method of sampling was developed by Mason.[1/]

RESULTS AND DISCUSSION

As shown in table 1, population reductions exceeding 95 percent were obtained within 7 days following treatment and nearly 100 percent by 14 days.

No problems were encountered in either the mixing or the application of the tank mix. An average of 11 gallons of spray was needed to treat each tree.

1/ Mason, R. R. 1970. Development of sampling methods for the Douglas-fir tussock moth *Hemerocampa pseudotsugata* (Lepidoptera: Lymantriidae). Canadian Entomologist 102: 836-845

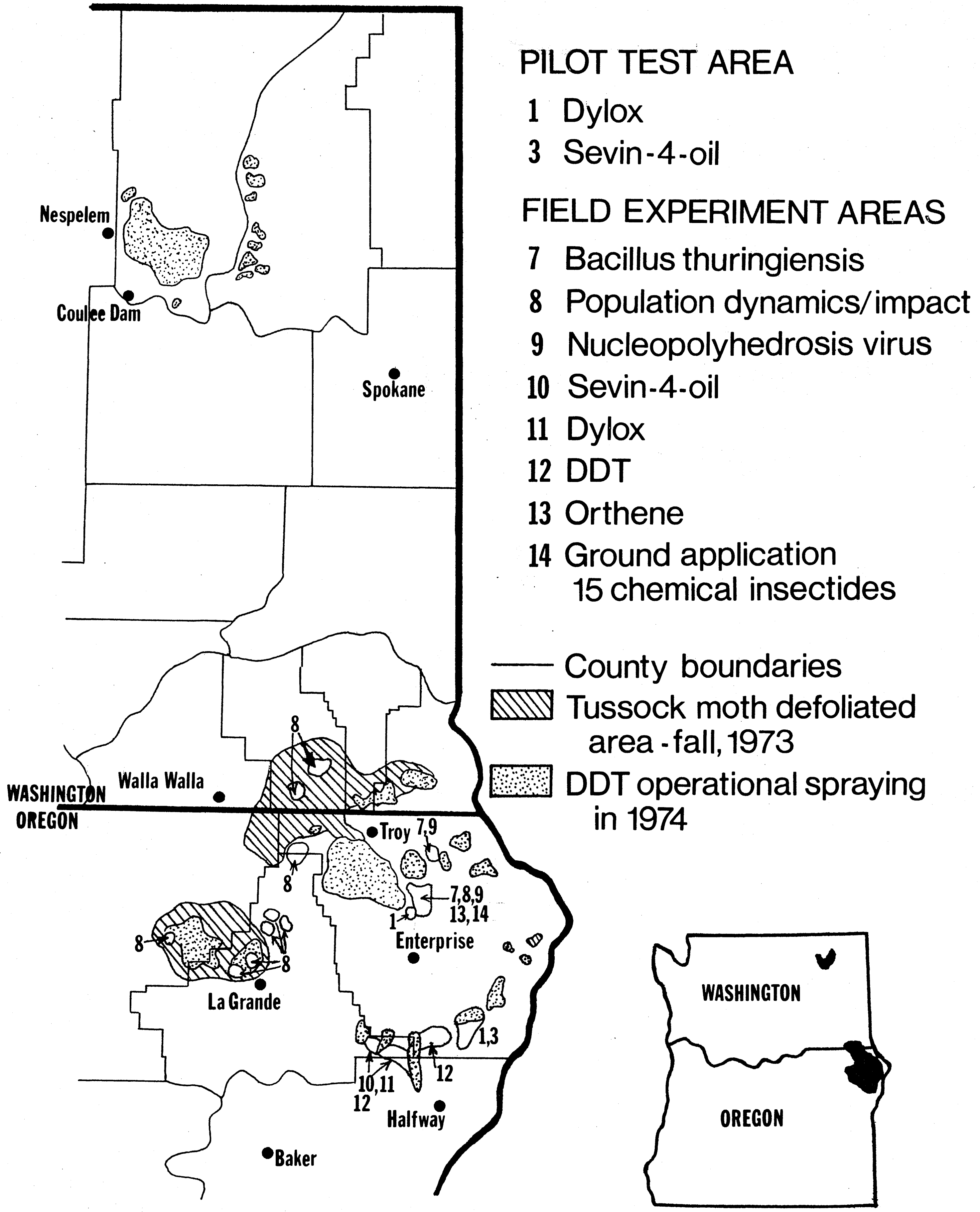
Table 1.--*Population densities of Douglas-fir tussock moth larvae on ornamental trees before and at 2, 7, and 14 days after hydraulic application of* B. thuringiensis

Treatment	Population density 1/				Percent population reduction		
	Prespray 2/	2-day postspray	7-day postspray	14-day postspray	2-day postspray	7-day postspray	14-day postspray
Dipel	361.56	103.92	13.27	0.91	71.3	96.3	99.7
Control	388.65	217.73	209.74	107.55	44.0	46.0	72.3

1/ Number of larvae per 1,000 square inches of foliage.

2/ 80 percent of population in second instar.

TUSSOCK MOTH Field Experiment and Pilot Test Areas, 1974



TUSSOCK MOTH Field Experiment and Pilot Test Areas 1974